

ARTISTS' PIGMENTS

THEIR CHEMICAL AND PHYSICAL PROPERTIES

By

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PREFACE

The numerous inquiries from artists and art students on the subject of the durability of the various materials employed in the fine arts, has encouraged the Author to prepare, in detail, technical matter as outlined in his different lectures.

The substance of the book is compiled in encyclopedic form, and to facilitate reference, an exhaustive index is appended.

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'ARTISTS' PIGMENTS

*INTRODUCTION

The study and thought which rightfully should be given the chemistry and technology of artists' colors, oils, varnishes, and vehicles unfortunately is often neglected by many artists, and frequently entirely overlooked by amateurs.

Too little time has been given in the past to the whys and wherefores of color pigments, their sources, durabilities and compatibilities, with which the artist desires to hand to posterity an interpretation of his ideals. The cry is growing continually stronger over the quick deterioration of some of our best examples of art. Anyone taking more than a passing interest in the world's art creations, cannot help but fear for their welfare during the next decade,—especially when seeing within a few years such change taking place, as fading, darkening, cracking and wrinkling among the most representative paintings of the various periods.

The disadvantages of the artist of a century ago need be but considered in comparison to what wonders the rapid advance of chemistry has done for our modern artist. Before 1800 the palette was limited to but a few and expensive colors. There were not known the brilliant and permanent Alizarin Lake Colors, and such rich pigments as the Cadmium Yellows, Chromium Greens Emerald Greens, Permanent Vermilions, Cobalt Greens etc. Prussian Blue was only discovered in 1704. On the other hand many brilliant but unsafe colors, have modern chemistry to thank for their discovery. The artist must know his colors in order to use but the safest on his palette.

Today the artist colorman must frequently offer against his better judgment and knowledge, unsafe colors such as Carmine Lakes, Mauve, etc., and it is regrettable, when such colors are unknowingly used, where permanency is desired. It is to be hoped, the unsafe colors will gradually become extinct owing to lack of demand, as has been the case with a few colors in late years. Some of these colors have caused the inexperienced user many tears of regret. Noteworthy to mention here is the one-time fad or craze for the use of bitumens, with well-known detrimental results.

A more intimate knowledge of the materials, which are used in the fine arts, not only stimulates a feeling of greater confidence in their use, but these same materials stand in closer relation to the user, if it be known exactly what their constituents are and that they have been prepared for a definite purpose, in a scientific manner, of carefully selected ingredients.

The days of manufacturing secrecy in the production of artists' colors and vehicles should be a thing of the past. At the beginning of the last century many colors were and have since been discovered and each manufacturer guarded his formulas and products in a most careful manner. For example, take the case of Prussian Blue. This color upon discovery was immediately produced by various colormakers and each naturally strove to have it regarded as a specialty of his own. Consequently this color was put on the market under quite an array of names; for instance, Turnbull's Blue, Paris Blue, Saxon Blue, Milori Blue, Chinese Blue, Bronze Blue, Berlin Blue, and lately also, American Blue. Gradually throughout the years that followed, the unuseful colors were discarded, but still many dangerous colors were offered to the profession who were entirely ignorant of their composition or technical qualities. To-day we stand in a position to call chemistry to our aid in deter-

mining the composition and compatibilities. In fact, it is to-day possible to synthesize some of the fugitive natural, vegetable dyes, obtaining substitutes, which are permanent and more brilliant.

There are on the market to-day a great many unnecessary colors appearing under various fanciful names, many dangerous aniline or dye colors, titled with misleading or alluring names, which mean nothing, but serve only to attract the unsuspecting buyer. Admixtures, to obtain unusual hues, can just as readily and more safely be made by the artist himself, to meet his special requirements, than by the manufacturer who is ignorant of the character of colors used in conjunction with the admixture.

The artist to-day has not the time to make his own materials, as in the days of the old masters, whose palettes were limited to but a few colors, and whose vehicles and pigments were only accepted by them after long years of tedious study and observation.

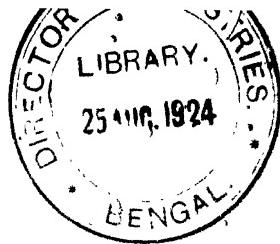
We are prone to credit the old masters and ancients, especially those from the time of Pliny about 77 A.D., to the end of the sixteenth century, with much technical knowledge concerning the composition of the materials they used. As chemistry was practically unknown as a science before the seventeenth century, how could the painter, before this time, possess knowledge only possible to obtain in comparatively recent years? The fact of their using mostly permanent pigments was not directly due to any scientific knowledge of the composition of their products, but was chiefly a matter of careful selection from an exceedingly small number of pigments, oils and varnishes at their disposal. Their organic colors were few in number, the innumerable, brilliant, but mostly fugitive synthetic dye-stuffs known to-day, date only from 1856.

The artists living during the eighteenth and early nine-

teenth century were unquestionably the most unfortunate. During these years chemistry was rapidly introducing new colors, many of which during their introduction were offered very impure and under misguiding and fanciful names. By doing this, the manufacturer thought to hide the identity of the color, and the artist was forced to select by standards of brilliancy only.

With the unlimited number of chemical and natural raw pigments, vehicles and sundry products offered today, it requires a wide and intimate knowledge of their composition in order to make a proper selection.

The purpose of this book is to educate the user, not in the use of his materials, but to bring to him, in a conversational and as interesting a manner as possible, the chemistry and technology of Artists Pigments.



PIGMENTS

The application and use of pigments in the manufacture of paints for artistic purposes is of great antiquity. In the earliest periods known we have evidences that prove conclusively that the ancients understood color-making and the use of colors for ornamentation. During the late centuries great industrial progress has developed the manufacture and selection of natural and artificial pigments for paint use. In this book we will, of course, only consider chiefly those paint pigments pertaining to the fine arts. These pigments are, however, the same as used in all branches and phases of paint making, both for artistic decoration as well as for protective requirements, the various techniques depending essentially on the respective vehicles or methods of manipulation.

We distinguish pigments from paints in that the latter are prepared from the former by the addition of a vehicle or medium. Pigments differ from dyes, as color-giving agents, by the fact of their being insoluble and chemically compatible with the vehicle employed, whereas the dyes are usually soluble.

Pigments in order to be termed and used successfully as such, should meet the following qualifications; be reasonably, or better altogether, permanent under exposure to light and air, chemically indifferent to each other in admixture, and not react with the vehicles employed or suffer thereby incalculable alteration in hue.

The important facts to be considered, when selecting pigments, are:

I. The chemical composition and physical properties of the pigment.

II. Whether the pigment is absolutely safe and dependable, durable and permanent to light, atmosphere,

gases, etc., reacts with other pigments or vehicles, and whether affected by these when in mixture. If only reasonably safe, or if not safe to use at all, why and in what instances, and what changes are likely to occur.

III. How the pigment is recognized chemically and physically. How detected from other pigments identical in optical appearance. Simple qualitative analysis, detection when adulterated or when in mixture with other pigments. Its chemical properties.

IV. Which pigments are natural or artificial products.

V. In what manner obtained and prepared, if of natural origin. If artificial, how made and from what various substances.

VI. Is it an opaque or transparent color, and as an oil color, does it influence the drying of the oils?

VII. To which painting techniques:—oil, water-color, tempera, pastel, fresco, stereochromy, etc.—is the pigment adaptable. If unsafe in certain techniques, why?

VIII. Does the pigment appear commercially under several names?

IX. Imitation pigments. How recognized and if the imitation has dangerous adulterants, how detected and which substitutes are best avoided.

Pigments when selected for the manufacture of artists' paints, require most careful inspection and testing of their chemical and physical properties. Permanency is perhaps the most important factor and the pigment should meet this qualification in its broadest interpretation; namely be permanent to light and air, in mixture with other pigments and vehicles and according to the technique in which it is applied, it should be water-proof, alkali-proof, acid resistant, gas-proof, lime-proof, etc.

Pigments are said to be gas-resisting when such gases most commonly met with, as Hydrogen Sulphide (H_2S), Sulphurous Acid Gas, Chlorine and Carbonic Gas do not react with them. Sulphur, either in the form of a sul-

phide or acid, is the one most commonly met with and the one which is the most important to guard against. This element is found in the gases coming from decaying or putrid animal and organic matter, marsh waters, or swamps and in coal gas. All the inert pigments, such as Permalba, Terra Alba, Asbestine, etc., along with Lithopone, Zinc and Sublimed Lead, Venetian and Indian Red, Ochre, Oxide of Chromium, all Blacks, all Blues excepting copper blues and all Brown earth pigments and Red Lakes which are free from lead, are practically gas-proof.

Pigments are said to be acid-resisting when no change is evident through reaction with such mineral or organic acids, commonly met with, as Oleic, Acetic, Sulphurous and Sulphuric Acids. Oleic Acid is present in the vegetable oils, also Sulphurous and Sulphuric Acids but the two latter only if not entirely removed from chemically bleached or refined oils. Acetic Acid is present in lead pigments that have not been properly washed.

Strong acids, which will more or less attack all pigments, rarely come in contact with finished paintings and the above mentioned weaker acids are representative to use in determinations. The pigments listed above as gas-resistant can also be accepted as acid-resistant.

Pigments are alkali-proof, if in the presence of ammonia or other alkalies they suffer no change; a test for which is to boil the pigment for ten minutes in a 10 percent solution of ammonia. All inert pigments with the exception of clays, whiting and Terra Alba (gypsum) which are slightly attacked, Venetian Red and Indian Red, Ochres, Oxide of Chromium, Siennas, Cobalt Blue, Permalba, Lamp Black and Ivory Black, etc., are practically alkali-proof.

Pigments that undergo no change after being mixed in lime water for twenty-four hours are practically lime-proof. This quality is greatly in demand since the inno-

vation of flat wall-paints for interior decoration. If lime is present in the wall, a spotting and noticeable dis-coloration of the non-lime-proof paint results. The following pigments are practically lime-proof: Permalba, Lithopone, Oxide of Chromium, Brown Earth Pigments, Red Lead, English Vermilion, Natural Iron Oxides, all Blacks, Cobalt and Ultramarine Blue, etc.

Permanency of Color Pigments in the fine arts is usually understood to convey that quality with reference to exposure to ordinary lighting or illumination. We will consider the permanence of individual pigments in their admixtures and for the purpose and with what vehicles or mediums they are intended to be used, when considering them separately.

Today the number of pigments available is very large. They are, however, mostly of simple nature, the number of elements entering into their composition not being large in number. Many beautiful and richly colored compounds cannot be accepted into the selection of pigments for artists' use, owing to their exceedingly fugitive character, lacking inertness and the required stability.

Pigments of which the constituent particles are homogeneous, such as most chemical colors, for example, Chrome Yellow, Vermilion, etc., are termed *substantive*. Pigments consisting of a colorless base, on which a coloring agent has been precipitated, such as the Lakes, Alizarin Crimson, for example, are termed *adjective*.

Lake pigments constitute a group, of which a great number are used in the fine arts, being known and used extensively by the early Italian painters. Pliny in the year A.D. 77 gives an account of them and explains the derivation of the term "lake." The lac, or coloring principle, of insect origin, used by the early Italian dyers for certain colors, was either the product now known under this name or an analogous body. This lac was used in conjunction with compounds of tin and aluminum to precipitate and fix the dye color on the fabric.

During the process of dyeing, some of the lac combines with some of the tin and alumina to form an insoluble compound, forming a colored scum on the top of the dye-vat. This substance, called by the Italian dyers, lacca, was collected, dried and offered to artists as a pigment. Soon other natural dye-stuffs were found to yield variously colored laccæ and methods were gradually evolved, whereby the lakes were obtained direct and not as a residue of the dye-vat. In fact, the manufacture of lake colors is today an industry ranking as important as the dye industry.

A lake pigment is not merely a mixture of dyestuff and an inert base. A pigment thus formed would not have the color-principle firmly fixed and would "bleed," that is, it would, in admixtures, especially in liquid solutions, give up the color again. In order to fix the color permanently onto the base, the treatment varies according to the character of the dye and base. The usual procedure is to precipitate the base from solutions in the presence of the dye, in solution. The color will then become so attached to the precipitated base, that it will not bleed, but forms an insoluble pigment.

The coloring principle of lakes is either of natural or artificial organic origin, and can be divided into two principal groups: I. That obtained from the natural coloring matters, such as lac, cochineal, Persian berries, Brazil wood, log wood, etc., and II. that obtained from the coal tar colors, which in recent years has developed to such an extent to almost entirely supplant the use of natural coloring matters, more brilliant and permanent lakes being obtainable.

The *extenders, carriers, or bases* on which the color to form a lake is precipitated, are inert and as nearly colorless and transparent as possible; the principal ones being Alumina Hydrate, Blanc Fixe, Paris White, China Clay. Therefore, all lake colors used in the fine arts are usually listed as transparent.

Pigments can be generally classified according to their origin or source, as follows:

Mineral Pigments	<i>Natural</i> ; as the Ochres, Siennas, genuine Ultramarine.
	<i>Artificial</i> ; as the Chromes, Cobalts.
Organic Pigments	<i>Animal</i> ; as Carmine, Sepia.
	<i>Vegetable</i> ; as Gamboge, Madder Lakes.
	<i>Artificial</i> ; as Alizarin Lakes, Indigo, etc.

Chemically, they can be grouped as follows:

- Elements; as Lamp Black.
- Compounds; as Chromes, Vermilions

NOMENCLATURE OF COLORS

The nomenclature of colors does not follow any systematic classification. Manufacturers and dealers are in the habit of calling a color pigment by names which are quite arbitrary. We find different names applied to a single pigment, or on the other hand, also many colors are offered under one name. The majority of colors, procurable from reliable sources, are sold by names more or less internationally recognized. Many colors are named after their inventors, others after their original or principal places of origin, or the locality in which they are found in nature; others after their ingredients; others after their resemblance to other colors; others after certain qualities they possess; others after the purpose for which they are intended and still others after the materials used in their production, etc. Perhaps the ideal nomenclature would be to express the chemical composition when naming a color; this, however, would be exceedingly impracticable owing to the lengthy chemical formulas and corresponding lengthy and perplexing scientific nomenclature, especially true of the colors of organic origin.

TECHNIQUE EMPLOYED IN TESTING

The artist or student interested in determining qualitatively the purity of any color should keep the necessary reagents for this purpose and refer to the various tests for each pigment in question, under its respective listing in the following chapter. A small wooden box should be kept in the studio, in which several bottles of necessary reagents may be safely kept, ready for use at any time. A limited number of the most necessary reagents are, a bottle each of

Water
Alcohol
Sodium Sulphide in Water Solution
An acid (preferably Hydrochloric, Sulphuric or
Nitric)
Ammonium Hydroxide
Red and blue litmus paper
About six test tubes and small glass funnel
Filter Papers

A more complete assortment to make the usual tests, should comprise a bottle each of

Water
Alcohol
Sodium Sulphide in Water Solution
Hydrochloric Acid
Sulphuric Acid
Nitric Acid
Ammonium Hydroxide
Sodium Hydroxide in Water Solution
Lime Water
Potassium Ferrocyanide in Water Solution
Ferric Chloride in Water Solution

Barium Chloride in Water Solution
Silver Nitrate in Water Solution
Red and blue litmus paper
About 6 test tubes with small glass funnel
Filter Papers

The technique employed in testing a color is as follows: Some tests may be made with Oil Colors, Water Colors, etc., without the oil or gums interfering to any great extent in the reactions. The pigment in the dry powder form responds to reactions more accurately and definitely. It is therefore necessary that the oils, gums, etc., be removed before testing the pigment.

The oil-color pigments should be washed free of the oil by squeezing a small amount, about a thimbleful, of the color in a test tube, adding turpentine in excess and shake until the color and turpentine are thoroughly mixed, allow the pigment time to settle, then filter and if necessary repeat several times, adding fresh turpentine, until all the oil is removed, leaving only the pigment upon the filter paper. Any turpentine remaining with the pigment should be removed by using alcohol in the same manner as the turpentine was used. It should now be observed whether the turpentine, or especially the alcohol, filtered off colorless; a colored solution would indicate the presence of soluble dye-stuffs or other soluble substances. Other volatile solvents such as Benzol, Toluol, Xylool, Benzine, Solvent Naphtha, Ether, Chloroform, Carbon Tetrachloride, Acetone, etc., are sometimes also employed to advantage, especially if the colors contain the addition of varnish gums. Some extremely fine pigments filter through with the first filtrate and the student should not mistake this for a colored solution, indicating dye-stuffs or other soluble coloring matter, as the solution usually filters clear after carefully refiltering. When dyes, etc. are present the filtered solution will remain colored even after refiltering several times. A water color pigment is

removed from the water soluble gums by using water in place of the turpentine, etc., as with the oil colors. The washed pigments should not be heated too strongly when drying.

We must first determine the chemical composition of the pigment in order to further test its purity and properties as a durable color. If the name of the pigment in question be known, reference should be made to the various tests employed in its detection, listed under its respective name in the following chapter.

If on the other hand the identity of the color is not known, reference should be made to the listing of several colors of similar appearance with their distinguishing reactions.

To illustrate this more clearly, let us, for example, assume that we have four blue pigments, which optically resemble each other very closely, and it is desired to know which of the four are desirable as durable pigments and of what they are composed.

We are primarily concerned with the composition and therefore shall test the four pigments to determine their composition; and after this is known, it is a simple matter to refer to the chemical and physical properties of each respective color as listed in the following chapter.

Each sample is first washed in water and then alcohol. If any of the four yield a colored filtrate, this would indicate the addition of a dye-stuff or other soluble coloring matter. The water filtrate may also be tested for soluble salts, as these are present should the pigment be insufficiently washed when made, or the salts may have been added as adulterants. Detection: allow the filtrate to evaporate to dryness on a shallow crystal when more than a mere trace of residue would indicate the presence of soluble impurities.

Next we make reference to the pigments commonly employed and in this instance find that Cobalt Blue Ultra-

marine and Prussian Blue, only seldom the copper blues represent the typical blue pigments. Upon comparing the various reactions common to each pigment, we see that upon the addition of sodium sulphide in solution, any of the four containing copper will be turned black and its further properties should be looked up, under its proper listing. The pigments which were not discolored by sodium sulphide are then given further test for Cobalt, Ultramarine and Prussian Blue. Cobalt Blue and Prussian Blue are insoluble in dilute acids, and by adding a drop of dilute hydrochloric acid to each sample, that which is Ultramarine will be reacted upon by the acid and may be further affirmed by referring to the characteristic chemical properties of this pigment. The Cobalt and Prussian Blue are physically so different that usually they are readily recognized, however knowing that Prussian Blue is reacted upon by alkaline solutions, the Cobalt Blue will remain unaffected upon the addition of this reagent and each may be further definitely recognized by distinguishing reactions listed under their chemical and physical properties.

The addition of any insoluble or inert extender, such as whiting, clay, barytes, alumina, silica, etc., may be detected by referring to the characteristic test for these substances. The tinting strength and color value of the pigment is greatly reduced when these are present in appreciable amount. The color may be compared in tinting strength and color with a known pure standard color. A simple method of doing this is to weigh off exactly the same amounts of each color and mix with an equal amount of pure zinc white, using the same quantity of oil for each. Compare the tint obtained from the sample pigment with the tint of the known standard.

PIGMENTS

In the following listing of colors, the colors are arranged in alphabetical order, irrespective of their various chemical and physical properties, the intention being to facilitate reference. Each color is listed by its most commonly recognized trade or scientific name. In the index at the end of the volume, various synonyms of the respective colors will also be listed alphabetically.

AIR BLUE

Azurite, Bergblau, Bice, Blue Virditer, Cendre Bleue, Chessylite, Lime Blue, Mountain Blue, Neuwied Blue, Blue Ashes, Copper Blue, Cenere Blue, Azul Ceniza, Bremen Blue.

Basic Copper Carbonate— $2 \text{CuCO}_3 \cdot \text{Cu} \cdot (\text{OH})_2$

Has very little covering quality, however of beautiful sky-colored blue. Although permanent to light, being a derivative of copper it is very sensitive. As an oil color it rapidly changes to dull green (reaction with fatty acids). In the presence of sulphurous gases, like all pigments containing copper, black copper sulphide is formed. (See page 187 for detection of copper.) It is lime-proof and finds use only as a fresco color, is unsafe in other techniques.

Obtained from native mineral Azurite (Chessylite) or artificially by precipitation from Copper Sulphate solution. This color is mentioned by Pliny in his "Naturalis Historia," A.D. 77.

Bremen Blue, consisting essentially of copper hydroxide, $\text{Cu}(\text{OH})_2$, is sometimes also employed as a fresco color. Being unsafe it is fortunately coming into disuse.

ALIZARIN LAKES

Aliz. Blue; Aliz. Carmine; Aliz. Crimson; Aliz. Green; Aliz. Orange; Aliz. Scarlet; Aliz. Yellow; Rose Madder Aliz.; Aliz. Madder Lake; Aliz. Burnt Carmine; Indian Lake Aliz.; Permanent Violet; Permanent Crimson; Aliz. Sap Green; Aliz. Olive Green; Aliz. Olive Lake; Aliz. Crap Lakes; Scarlet Crap Lake; Violet Crap Lake; Laque d' alizarine carmiosie; Laqua d' alizarina cremisina; Laqa de garanza cramois; Alizarin Farben

Alizarin $C_{14}H_6O_2(OH)_2$ is the active coloring principle.

Yields very permanent and brilliant lake colors, which may be considered the representative lake colors for the fine arts. The coloring principle is, with few exceptions, precipitated on a neutral base of Alumina Hydrate, which, as a pigment yields, when ground in oils or gums, very brilliant, transparent colors.

Before the development of the Alizarin colors from anthracene, a coal-tar derivative, the madder root was the source of this color extraction for many centuries. The madder root has two important coloring principles: *Alizarin* $C_{14}H_6O_4$ and *Purpurin* $C_{14}H_6O_5$, the Alizarin yielding the more permanent lakes of brilliant crimson, rose, purple, violet and maroon hues, varying according to the concentration, purity and base upon which it is precipitated. Purpurin yields pigments more orange or red in hue. The synthetic or artificial Alizarins are rapidly displacing the madder extracts, being of richer hue if properly manufactured and more permanent. They are of identical chemical composition to the root madders.

Sodium Hydroxide entirely dissolves Alizarin and Madder Lakes (on alumina base) to a blue-violet solution (Purpurin yields a cherry-red solution), which, upon the addition of dilute Sulphuric Acid in excess, loses its color with formation of a flocculent, colored precipitate of

the dye-stuff. (orange-yellow in color if Alizarin and bright red if Purpurin), leaving the supernatant liquid practically colorless. Carmine or Carmine Lake are detected by their leaving the acidified solution more or less intensively red in color.

Alizarin and Madder Lakes are insoluble in water or alcohol; a colored solution would indicate the addition of dyes.

All lakes, including the Alizarin Lake colors, are not practical for fresco or stereochromy, proving fugitive and unsafe in these, but for most every other technique the Alizarin Lakes are absolutely safe and permanent.

Alizarin Madders and Madder Lakes are perfectly durable and safe in admixture with the calcined or burnt earth pigments, such as Bt. Sienna, Bt. Umber, Bt. Ochres, Burnt Iron Oxide Colors, Burnt Ferre Verte, etc., but not always with the natural earths, such as Raw Sienna, Raw Umber or Raw Ochres, due to the presence of iron hydroxide in these pigments. The chemical colors such as the White Leads, Chrome Yellow, Naples Yellows, Chrome Greens, etc., have a tendency to somewhat bleach the Madder Lakes; Genuine Vermilions, Cadmium Yellows and the Black pigments, however, do not affect them. The Alizarin Madder Lakes, as also the Madder Lakes, yield brilliant and permanent results if applied as a glaze over colors which are thoroughly dry. Permalba with Alizarin or Madder Lake yields tints of highest color value and dependable permanence and durability.

ALUMINA

Aluminum Hydrate

Aluminum Hydroxide— $\text{Al}(\text{OH})_3$

An amorphous, translucent substance, insoluble in water. It reacts with acids, forming the corresponding aluminum salts; also reacts with strong bases. On

strongly heating Aluminum Hydrate it is converted into the oxide.

Owing to its physical characteristics it is the ideal base on which to precipitate many organic dye-stuffs to form transparent lake pigments. See description of lake pigments, page 74.

AMERICAN VERMILION

Imitation Vermilion, Vermilionette, Persian Red,
Derby Red, Victoria Red, Vienna Red

A color of varying composition, consisting usually of a base of Red Lead, tinted with Eosine dye, to yield a brilliant substitute for the genuine quicksilver vermilion. The greater number of American Vermilions are not very permanent to light; however, there are some in which the fugitive Eosine dye, has been displaced by more permanent toners, yielding pigments very permanent (to light). Owing to the base of red lead, it is opaque and it is to be classed with all the lead colors; to be used only with limitation. Discolors in presence of sulphurous gases. Heat destroys the color. Can be recognized from pure mercuric vermilion by their partial solubility in alkalies, or dilute acids, or upon treatment with alcohol, by parting with most, or all, of their dye coloring matter, the genuine quicksilver vermilion resisting these reagents. Sodium Sulphide converts the lead constituent to black lead sulphide.

Red Lead and *Chrome Red* with barytes or lead sulphate are the most common carriers used with toning colors, to produce very rich hues of American Vermilion.

• *Chrome Red*, the most basic lead chromate $PbCrO_4$. PbO —is sometimes sold as American Vermilion, but owing to its high specific gravity it separates quickly when ground in oil and is only used in fresco with a certain amount of success. Chrome Red has also the limited fastness of all lead colors.

In oil, American Vermilion, is a good dryer and in the heavy paint trade is especially recommended for its rust protective qualities, when applied on metals.

ANILINE COLORS

(See Coal-Tar Colors)

ANTWERP BLUE

Bleu mineral, Bleu d'Anversa, Azul de Amberes,
Antwerpener Blau.

Prussian Blue, weakened in strength, with Alumina.

Antwerp Blue, a product of iron and zinc cyanogen compounds, yielding a color paler than Prussian Blue, has more recently been replaced with above mentioned Prussian Blue, reduced in color strength with Alumina.

The properties of this color are almost identical with those of Prussian Blue (which see).

ASBESTINE

Hydrated Metasilicate— $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$.

Used principally in the heavy paint trade as a neutral carrier, or extender in ready mixed paints, to prevent settling of pigments heavy in gravity. Finds no practical use as a pigment for fine arts.

Asbestine differs from Asbestos, a calcium magnesium silicate of varying composition, by its short fibre, the asbestos having a long fibre.

To the native Magnesium Silicates belong also *Talc*, *Talcum*, *Soapstone* or *Steatite*, *French Chalk* (a hydrated Magnesium Silicate; $3\text{MgO} \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$) and also another variety of this compound, *Mberschaum*.

These compounds are not very important in the fine arts, being of very soft body, transparent and do not yield brilliant lake colors, when used as bases. Talc finds use for polishing marble and gypsum articles and also in the manufacture of face powders, etc.

ASPHALTUM

- Bitumen, Mineral Pitch, Antwerp Brown, Mummy, Bitume, Asfalto, Asphalt.

A natural mixture of solid hydrocarbons, very often containing also sulphur and nitrogen compounds, generally considered to be a product of the decomposition of animal and vegetable matter.

Under this group we have a variety of pitchy, tarry substances ranging in color from brown to black, found principally native in the great pitch lake of Trinidad. The best quality, used for artists' paints, is obtained from the Dead Sea. This Syrian Asphalt is of rich brown color, exceedingly hard with bright and lustrous surface fracture, melts at 135° C. with a characteristic bituminous odor; is slightly soluble in Alcohol or Ether, more so in Benzol and dissolves entirely in Turpentine or Linseed Oil.

Strong acids, such as Nitric Acid or lyes, do not affect this pigment, which property makes it particularly useful in the manufacture of etching grounds.

Asphalt as a color pigment is used only as an oil color. By virtue of its solubility in the vehicle of oil, yielding a very transparent paint, it resembles the transparent lake colors.

The Asphaltums decompose in direct sunlight. In presence of moisture, combined action of the oxygen of the air and the actinic rays of light, favor the combination of the oxygen and hydrogen, setting the carbon free, thus producing a dull black color. This is especially noticeable in admixtures of Asphaltum and white pigments; the resultant warm tints on exposure to light are changed to dull grays.

When used for under-painting, the Asphaltums 'bleed' or diffuse through the overlying layers of paint, darkening them, this being due to solubility in the oils, of the

asphaltums. Asphaltums are very poor dryers, even when used in conjunction with the best siccatis. They enter largely into the manufacture of varnishes, partly as coloring principle and partly as a resinous matter.

As an oil color, the Asphaltums are very treacherous when applied in thick layers. On the surface they appear dry, but even after years, exposed under strong summer heat, they soften and "slide" off the surface of the painting.

The Asphaltums, especially when applied in heavy layers, tend to crack on the surface.

Carefully selected Asphaltums when properly treated to extract the number of liquid, semi-liquid and solid colorless hydrocarbons, which have no color-giving value as a pigment, are not given to cracking or moving on the canvas like the unpurified material and if used with precaution will yield fairly good results; however, not to be recommended where permanency is desired.

The modern coal-tar pitch browns, offered as substitutes for the Asphaltums are far more treacherous on account of their easy fusibility and are more liable to stain contiguous pigments by reason of their solubility in oils or varnishes.

The safest substitute for Asphaltum is found among the Alizarin Lake Colors, or mixtures of Raw Sienna, Bt. Umber and Carbon or Ivory Black.

Mummy is a bituminous product associated with animal remains and derives its rather gruesome name from its source. The bituminous matter used in the embalming of the Egyptian mummies is perhaps the active coloring principle. Through the lapse of time the bituminous matter of the mummy, having been subjected to a considerable degree of heat, has lost some of its volatile hydrocarbons and ranks as a pigment superior to the raw and inferior to the refined Asphaltum. This color is gradually becoming extinct in the fine arts, as it does not

possess any quality not embodied in the refined Asphaltums. It was usual to grind up the entire mummy, thus the resulting powder had more solidity, was less fusible than the native Asphalt and less transparent than the refined Asphaltum. Mummy was used as an oil paint as early as the close of the sixteenth century.

AUREOLIN

Cobalt Yellow, Jaune Indian
Aureolin, Aureolina, Kobaltgelb

A yellow crystalline compound salt of the metal Cobalt.
Double Nitrite of Cobalt and Potassium - $\text{Co}_2(\text{NO}_2)_6 \cdot 6\text{KNO}_3$.

If precipitated in chemically pure condition, as a fine powder, the pigment is of pure yellow color, transparent, very slightly soluble in water. On account of its complex chemical composition if not properly washed of soluble salts, it is not absolutely dependable. It is very fast to air and light, and is unaffected by sulphuretted hydrogen, H_2S , although blackened by sodium sulphide or caustic soda. Like many other mineral pigments Aureolin when in admixtures with certain organic pigments, such as the lakes from cochineal, indigo, etc., causes decomposition of these; the organic colors becoming altered in hue as also the Aureolin itself becoming of a brownish hue. Various other yellow pigments of different chemical composition appear on the market under the name of Aureolin.

The genuine Cobalt Yellow is only adaptable to Oil and Water Color techniques and if chemically pure is considered permanent.

Cobalt Yellow is converted into black cobalt oxide by gently heating in a bunsen flame. Like all cobalt compounds a blue glass bead is formed, when heated with borax on a platinum wire. This pigment was introduced about 1861.

AURORA YELLOW

(See Cadmium Yellow)

A very brilliant variety of Cadmium Yellow of greater opacity than the regular Cadmium Yellow.

AZURE BLUE

Sky Blue

A mixed pigment consisting principally of Ultramarine Blue and Zinc Oxide or Permalba to yield a warm light Sky Blue color, contrasting with the cooler greenish (in undertone) Cerulean Blue.

The physical and chemical properties are identical with those of Ultramarine and Zinc White (Chinese White) or Permalba.

Azure Blue is fairly opaque and permanent to light and air and adaptable to all techniques.

BISTRE

Brown Lake, Soot Brown, Bister

The tarry soot from resinous pine wood or beech wood, which is ground to a fine powder from a lumpy condition and washed with hot water until the latter does not extract any more soluble matter from it.

Bistre is only met with in Water Color.

Like all bituminous organic brown pigments, under exposure to light, oxidation of the organic substances takes place, leaving a residue of carbon, thus changing the color to a cooler hue and paler. The greater the amount of tarry matter present in the pigment, the more fugitive the color.

Bistre will burn almost entirely, leaving only a trace of ash. When heated in a test tube, a tarry distillate is obtained, minute drops of tar appearing on the wall of the test tube.

BLACK LEAD

(See Graphite).

An allotropic crystalline form of Carbon.

BLUE BLACK

Charcoal Black, Vine Black, Frankfort Black,
Noir de Vigne, Rebensolwarz, Drop Black,
Noire bleuâtre, Nero bleustro, Negro azulado,
Frankfurter Schwarz.

The active coloring principle is Carbon, in the form of charcoal.

By dry or destructive distillation of grape husks, vine twigs, vine wood and other similar materials, various qualities of Blue Black are obtained. The finest quality is the Frankford Black, obtained from spent wine yeast, which, after carbonizing, is thoroughly washed, to free it from small quantities of potash and calcium carbonate derived from the "Tartar" in the wine yeast. When mixed with white pigments pure grey tints are obtained with a bluish tinge.

Blue Blacks have very little opacity as pigments; are, however, absolutely permanent, adaptable to all techniques. Like all carbon pigments they resist acids or bases, are insoluble in ordinary solvents and only oxidize at high temperatures.

A significant peculiar property of all charcoals in that they withdraw the majority of organic coloring matters from suspension and even from solutions in water, is evidenced, for instance, when a small quantity of Blue Black is added to a pale tint of Rose Madder in water. The tint becomes rapidly decolorized altho not really destroyed, the pigment being completely absorbed by the Black. Animal charcoal, such as Ivory Black or Bone Black are more energetic agents in removing gases and

coloring matter from solutions. This property is sometimes made use of in the purification of polluted water.

Charcoal Blacks are mentioned by Pliny in his "Historia naturalis," A.D. 77, and were perhaps the first black pigments used by man in the most remote ages.

BONE BROWN

Negro de Nueso, Beinbraun

By gently calcining bones or ivory chips, until they acquire a brown color, and thoroughly washing them, a warm brown pigment is obtained. Due to the presence of some undecomposed animal matter, Bone Brown, like most all organic browns, under exposure to light, fades. An undesirable pigment where permanency is required. Bone Brown, as used in the fine arts, is frequently a mixture of Ivory Black and Burnt Umber. This mixture is thoroughly reliable as a pigment in all techniques.

BRILLIANT YELLOW

Jaune Brilliant, Amarillo Brillante

A color resembling Naples Yellow in hue, prepared by a variety of mixtures, principally consisting of Cadmium Yellow, Vermilion, and White Lead.

Brilliant Yellow is very opaque and owing to the presence of White Lead, like all pigments containing lead it will discolor in presence of sulphur gases. Should the Vermilion or Cadmium used in the admixture contain free sulphur, discoloration will also occur. It can very easily be dispensed with as unsafe for the artists' palette. When Permalba is used in place of White Lead the color is unaffected by sulphurous gases and is then a very desirable color for permanency and durability.

BROWN MADDER

Garance brun rouge, Garance bruna rossa,
Garanza roja parda.

A brown lake prepared from the madder root. When the coloring principle of the madder root is precipitated with more or less alumina as a base, in association with the oxides of iron, manganese or copper, various hues are obtained, among which the principal are Madder Brown and Madder Purple.

The Alizarin Madders (which see) are used principally today in place of the Madder extracts and yield more permanent pigments.

Brown Madder is not as transparent as the Alizarin Lakes, but has practically the same physical and chemical properties as the Alizarin Lakes.

BROWN OCHRE

The coloring principle is hydrated iron oxide, a native species of which is *Limonite*— $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$.

It has all the chemical and physical properties of the Ochres (which see).

BROWN PINK

Stil de grain brun, Stil de grain bruno, Stil de
grain brun

A very fugitive lake pigment prepared from quercitron bark of three species of North American oak. Brown Pink is a deep variety of quercitron lake, which was formerly made from the berries of one of the species of buckthorn (*Rhamnus*) and principally precipitated on a base of Alumina Hydrate to yield a transparent lake. This color was known in the time of Pliny, A.D. 77. (See Yellow Lakes.)

Brown Pink is imitated by using some of the very permanent and alkali-proof yellow lakes, which are products

of the modern chemical color industry and should be used by the artist in preference to the fugitive genuine Brown Pink.

BURNT CARMINE

By gently roasting genuine Cochineal Carmine, a lake of deep rich purple hue is obtained, which shares the objectionable fugitive quality of the genuine Carmine (which see).

BT. ROMAN OCHRE

A calcined native earth, identical to the Ochres in chemical and physical properties.

BURNT SIENNA

(See Ochres)

Terre Sienna brûlée, Terra di Siena bruciata,
Tierra Siena tostada, Gebrannte Sienna

Calcined or roasted natural Raw Sienna. The iron hydrate, which is the yellow color-giving principle of the Raw Siennas, is converted by calcination into the red iron oxide, Fe_2O_3 , thereby considerably changing the translucency and deepening the hue of the pigment.

The Siennas like Umbers doubtless originally took their names from the localities in which they were first found. Analogous native earth pigments are obtained in different countries, but for the fine arts the best are still the Italian Siennas. They appeared on the palettes of the early school of painters and belong to the safest colors for all techniques, being exceedingly permanent and moderately transparent and useful in admixtures with other pigments. An inexpensive pigment, it is not liable to adulteration. Hydrochloric acid dissolves the iron of the ochres and siennas, forming a yellowish solution of iron chloride. The earthy and clay constituents remain a residue.

BURNT TERRE VERTE

Verona Brown, Terre Verte brulée, Tierra Verde Tostado, Gebrannte Gruene Erde

A calcined variety of the natural Terre Verte or green earth (which see).

Burnt Terre Verte is thoroughly dependable in all techniques, being permanent, semi-transparent and of ochre-brown hue.

BURNT UMBER

Terre d' ombre brulée, Terra d' ombra bruciata, Tierra de sombra tostada, Gebrannte Umbras

A calcined variety of the natural Raw Umber.

Raw Umber (which see) is a variety of Ochre and obtains its color from the large amount of iron hydroxide and oxides of manganese, present in its composition. Through roasting there is a consequent loss of water, resulting in a conversion of the iron hydroxide to iron oxide, thus yielding a warm reddish-brown hue. Being an inexpensive pigment, it is not liable to adulteration.

This permanent, semi-transparent pigment is in use since classical times, proving safe and adaptable to all techniques.

True Umbers are unaffected by lyes. Due to the presence of manganese oxides, hydrochloric acid evolves chlorine gas when warmed with this pigment. This reaction distinguishes it from Vandyke Brown.

CADMIUM YELLOW

Cadmium Yellow Lemon or Citron, Light, Medium and Deep, Cadmium Orange, Aurora Yellow, Orient Yellow, Daffodil, Sulphide of Cadmium, Jaune de Cadmium, Giallo di cadmio, Amarillo de cadmio, Kadmiumgelb

All hues are of the one compound of Cadmium and Sulphur, namely *Cadmium Sulphide*—CdS.

The pigments Cadmium Yellow medium, deep and orange consist only of the Sulphide of Cadmium and are the most permanent of the Cadmium Yellows. The lemon or citron and light tints of Cadmium Yellow are usually not the pure sulphide, but the same in combination with flowers of sulphur, zinc or white pigments, and are then invariably not quite as permanent as the medium or deeper hues.

The metal Cadmium was discovered by Stromeyer in 1817 and about 1846 the sulphide of Cadmium became recognized as a desirable and useful pigment.

By injecting a stream of hydrogen sulphide gas into an acidified solution of a Cadmium salt (usually Cadmium Chloride or Sulphate in solution) a precipitate of yellow Cadmium Sulphide is obtained, which must be thoroughly washed of any soluble impurities. It is essential that there be no free sulphur present in the pigment, which is especially likely to occur if the pigment has not been obtained by precipitation, but by heating Cadmium Oxide in a covered crucible with pure Sulphur in excess. It is necessary that all the chemicals used in making the pigment be absolutely chemically pure, as traces of iron, lead, bismuth, copper or any other metal, giving a colored sulphide, would materially alter the hue and brilliancy of the desired color.

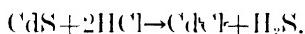
The wet process is in favor industrially in the manufacture of Cadmium Yellows. The Sulphide of Cadmium will vary in hue from light yellow to a fiery orange according to the concentration or strength of the solution of the Cadmium salt, the temperature and the length of time the solution is digested with the hydrogen sulphide gas, and whether the solution be neutral or slightly acidified.

The medium and deeper hues of Cadmium Yellow are normal colors, *i.e.*, they are permanent and are invaluable as artists' oil and water color pigments. The

paler Cadmiums are more likely to fade slightly. The Cadmium Yellows have a fair covering quality but are not safe to use in fresco or stereochromy (mineral painting) as they are acted upon by bases.

A Cadmium Yellow, which is chemically pure is perfectly safe in admixture with White Lead oil color. Emerald Green oil and water color, when mixed with Cadmium Yellows, will be rapidly destroyed.

Owing to the cost of chemically pure Cadmium Yellow pigments there is great temptation to adulterate with Chrome Yellow, Strontium, Zinc or Barium Chromates, etc. Chrome Yellows being the least expensive are most commonly employed. They can easily be detected by the production of black lead sulphide if the pigment under observation is treated with hydrogen sulphide gas, or a solution of sodium sulphide. Discoloration will not take place if the pigment be pure Cadmium Sulphide. Pure Cadmium Sulphide is entirely dissolved, when warmed with concentrated hydrochloric acid, forming a colorless solution of cadmium chloride and hydrogen sulphide gas:



If adulterated with Chrome Yellow, the solution will be of green color (formation of chromic chloride by reduction of the chromic acid by hydrogen sulphide).

Sodium hydroxide or potassium hydroxide precipitates white cadmium hydroxide from solutions of cadmium chloride, which is insoluble in an excess of the reagent.

Mixtures of Cadmium Yellow and Lead White are offered under the name *Jaune Brilliant*, which color should be used with caution on account of the presence of lead. Cadmium Yellows when mixed with Permalba or Zinc White yield tints closely resembling the true Naples Yellows and being more permanent are advisable to use in place of the latter.

Aurora Yellow consists principally of cadmium sul-

phide, being a very brilliant, more opaque variety of this pigment.

Neutral Orange is a mixture of Cadmium Yellow with Venetian Red.

Cadmium Red, a modern pigment, is a mixture of Cadmium Sulphide and Cadmium Selenide. It is perfectly permanent to light and in other respects as safe as the Cadmiums. Frequently used in place of genuine mercury vermilions on account of permanency, it nevertheless is not quite as brilliant as these.

Cadmium Red dissolves to a colorless solution in concentrated hydrochloric acid with evolution of hydrogen sulphide and hydrogen selenide. Adulteration with barytes would be indicated by an insoluble residue of the same.

CALEDONIAN BROWN

Brun de Caledonie, Bruno di Caledonia, Pardo
de Caledonia, Kaledonish Braun

A natural earth pigment, a species of Umber receiving its color from the brown hydrates and oxides of manganese and iron. The genuine English Caledonian Brown, like the Umbers, is a normal pigment. The color appears mostly as an imitation produced by admixtures of Siennas and Umbers, a less permanent imitation is made of Vandyke Brown and Bt. Sienna. See Raw Umber for chemical properties.

CAPPAH BROWN

Pardo de Cappah, Kappahbraun

This color comes under the classification of the natural Umbers, receiving its rich red-brown color from the presence of iron hydrates and oxides and considerable amount of manganese oxides (see Umbers).

Cappah Brown was originally mined in Skibbereen, in the county of Cork, about 1814, but is today obtained

from various sources, its composition varying considerably according to the locality from which it is obtained. Many samples contain Bitumen and are, therefore, not safe. Admixtures of Bt. Umber and Bt. Sienna to obtain this hue are more safe, than those made of Bt. Sienna and Van. Brown.

The color can very easily be dispensed with by the cautious artist, unless assured of the permanence of the brand to be used. For chemical properties see Raw Umber.

CAPUSINE MADDER

A permanent lake color of beautiful rich reddish-brown hue of good permanence to light.

CARBON BLACK

Gas Black, Gas Soot, Velvet Black
Noir de charbon, Nero Carbon, Negro de carbon,
Kohlenschwarz

Consists chemically of the element *Carbon*.

Carbon Black is in all physical respects similar to Lamp Black but is more intensely black in color. Although not crystalline in structure, it has the appearance of such, being granular in form.

In the manufacture of it, Carbon Black differs from the true Lamp Blacks, which are obtained from the combustion of oils, by being made from the combustion of gas. In America, principally in many of the oil regions, the natural gas, which flows out of the ground is utilized for this purpose. The flames are cooled by iron plates on which the soot or carbon Black becomes deposited and is collected.

Carbon Black is the purest form of the Carbon Blacks, viz., Ivory Black, Lamp Blacks and Charcoal Blacks, and like these, resists acids and bases, is absolutely permanent and adaptable to all techniques. Only at exceeding-

ly high temperature the carbon unites with oxygen in the air, yielding the gas, carbon dioxide, leaving no ash residue. Being an extremely poor dyer in oil, it also retards drying of admixtures with other colors and on account of its great tinctorial strength or intense coloring properties, it stains every other color with which it may be mixed.

CARMINE

Carmine Lakes, Carmine II, Crimson Lakes,
Purple Lake, Scarlet Lake
Carmin, Carminio, Carmin, Karmin

This beautiful rich crimson red color is obtained from the dried dead wingless female cochineal insect (*Coccus Cacti*) which feeds upon several species of cactus, being principally indigenous to Central America, Mexico, and cultivated in Algiers, the West India Islands, the Canaries, and Southern Spain. It appears in two forms on the market, as small shining black shriveled granules (black Cochineal) and small grayish dust-colored oval grains (gray Cochineal). The Cochineal insect is still cultivated on large plantations. The dye has been an important commercial product since the conquest of Mexico, 1523, but has been almost entirely displaced as a dye by the modern coal-tar dyes. Lake pigments were prepared from it, since the early sixteenth century.

The best kinds of Cochineal consist of about one-half their weight in red coloring matter, to which the name *carminic acid* has been given. This fine crimson extract can be obtained from the insect by boiling it in water, when, on the addition of small quantities of acids or saline substances such as alum, a very fine red powder is deposited. This pure carmine is sold in powder form or pressed into small blocks.

Various hues are obtained by varying the bases, thus by the presence of iron, manganese or copper generally

dull hues are obtained; a small quantity of lime present, will yield a purplish hue. (*Purple Lake*). The finest quality is known as "nacarat carmine."

Pure Carmine and Carmine Lakes are practically insoluble in water, but are readily dissolved by ammonium hydroxide. Pure Carmine leaves less than 10 percent ash when calcined. This reaction serves to distinguish pure Carmine from Carmine Lakes and other lake pigments, the greater the amount of ash or residue the larger the amounts of base (Alumina, Clay, etc.) upon which the color was precipitated. Pure Carmine is entirely soluble in dilute sodium hydroxide. Upon the addition of an excess of dilute hydrochloric acid to this solution the color remains in solution, as carminic acid—deep red in color. This distinguishes Carmine from Aliz. Madders, which would precipitate from the acid solution.

Carmine is soluble in strong ammonia liquor and the caustic alkalies, but insoluble in all usual organic solvents.

The commercial methods of manufacture are kept more or less secret by the various color makers, a very inferior pigment being usually obtained from published recipes. The usual procedure is, however, to extract the color from the Cochineal, the first precipitate yielding Carmine and from the filtrate liquor the various carmine lakes are obtained by precipitating the dye, which remains in the liquor, on the base of alumina hydrate. The Cochineal lake pigments are, therefore, weaker and less brilliant in hue, but like Carmine have the objectional fugitive quality.

Carmine, Carmine II and Carmine Lakes are exceedingly fugitive, bleaching not only by action of sunlight in very short time, but also are destroyed by many of the metallic pigments in mixture. They decompose in admixtures with the raw earths becoming brownish in color during process of fading. They dry fairly well in oil and like most all lake pigments are translucent.

Carmine may be regarded as the highest, purest and most concentrated lake of the series of lakes derived from this source. The Alizarin Coal Tar Lakes have in recent years almost entirely displaced the natural Carmine and its lakes, the former yielding dependable, permanent and more brilliant lakes.

Burnt Carmine. By partly roasting or calcining Carmine a beautiful deep rich hue is obtained, which shares the same lack of permanency as the Carmine from which it is derived.

Pure Carmine is non-poisonous and is used in the manufacture of face powder, and as a coloring for candies and other food stuffs, etc.

CASSEL EARTH

This color is synonymous with Vandyke Brown, which see.

CERULEAN BLUE

Coeruleum, Bleu celeste, Cörlulum, Cölinblau

Blue ceruleum, Azul celeste

Consists principally of *Cobaltous Oxide*, CoO and *Tin Oxide*, SnO_2 .

This light greenish-blue pigment is very permanent, almost opaque, is adaptable to all techniques, safe in admixture with other pigments, and has only limited tinting power.

Cerulean Blue is usually obtained by precipitating a solution of Cobalt Chloride— CoCl_2 —with potassium stannate, thoroughly washing the precipitate and then mixing it with pure silica and heating. Another method is to moisten tin oxide— SnO_2 —with cobalt nitrate solution, strongly heating, then powder and wash the greenish blue mass which is developed, thereby obtaining a variety of Cerulean Blue known as *Coeruleum*.

When viewed by artificial light Cerulean Blue does

not acquire a violet cast, so noticeable with other cobalt blues. By admixture of ultramarine, viridian, and zinc white and imitation of this color is obtained, lacking, however, the distinctive characteristic cerulean hue. A more permanent imitation can be made with Cobalt Blue, Viridian, Zinc White or Permanent.

- Cerulean Blue is practically unaffected by weak acids and alkalis.

The simplest method for determination is the deep blue glass bead formed when cobalt compounds are fused with Borax on a platinum wire.

CHARCOAL GREY

Gris de charbon, Grigio carbon, Gris de carbon

Made by grinding the charcoal obtained by charring soft woods. Consisting principally of Carbon, like the Lamp Blacks, Ivory Blacks, and Blue Blacks, which it resembles chemically and in physical properties. It is, when washed free of any soluble matters, a permanent pigment for use in all techniques with but little tinting strength and little opacity. Is usually reduced in tone with Zinc White. See Lamp Black.

CHINESE BLUE

Synonymous with Prussian Blue

A ferricyanide of iron, *Ferric Ferrocyanide*— $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$.

Refer to Prussian Blue for chemical and physical properties.

CHINESE ORANGE

This beautiful rich brownish-orange color is a lake pigment made from a derivative of coal-tar alizarin, precipitated on a base of Alumina. This color shares the physical and chemical properties of the Alizarin Lakes (which see).

CHINESE VERMILION*Sulphide of Mercury*—HgS

This quicksilver vermilion derives its name from the especially brilliant pigment obtained from China. It is chemically and physically identical to English and French Vermilion and other hues of genuine Vermilion, such as the Scarlet, Orange, etc. (See Vermilions).

CHINESE WHITE'

Blanc de Zinc, Bianco di Zinco, Blanco de Zinc,
Zincweiss
Oxide of Zinc—ZnO

This very brilliant white pigment is an especially selected pure Zinc White, used in Water Color to produce a permanent and opaque color. This color was not originally made in China as the name might imply, but was first introduced in France about the middle of the nineteenth century and probably given its name to hide its origin.

It adapts itself as an ideal Water Color, Tempera and fresco white, having the permanent qualities and physical properties of Zinc White.

CHROME GREENS

Chrome Green light, medium and deep, Zinnober Greens, Cinnabar Greens, Zinc Green, Green Vermilions, Cinabro Verde, Cinabre vert, Cincabrio verde

Consists of mixtures of Prussian Blue and Chrome Yellow pigments in varying amounts to yield hues from the palest yellow-green to the deepest blue-green.

These Chrome Greens should not be confused with the Chromium Greens, namely the transparent hydrated oxide of Chromium (Emeraude Green) or opaque Oxide of Chromium, which are permanent and very desirable colors.

Admixtures of Emeraude Green with Cadmiums, Zinc Yellows or Strontian Yellow yield permanent and reliable Chrome Greens. On the contrary Prussian Blue with Gamboge or Yellow Lakes, being of organic origin are prone to oxidize and are not as permanent to light. Ultramarine Blues with yellow pigments yield dull and frequently unreliable mixtures.

The Chrome Greens of commerce are mostly mixtures of Prussian Blues and Chrome Yellow or Zinc Yellow. When Prussian Blue and Zinc Yellow are used the resultant hues of green are frequently called Zinc Greens. The Zinc Greens possess the advantage over the Chrome Greens in that they are not sensitive to sulphur and are more permanent to light.

Chrome Greens are usually mixtures of blue and yellow on a barytes, clay or mixed base. In the manufacture of Chrome Greens great care must be taken, that the ingredients are chemically pure and careful selection must be made of the hues and chemical properties of the blues and yellows to be used. The greens obtained by mixing the colors in a wet condition are more intimately mixed than those made by grinding the colors together in a dry state.

The Chrome Greens are opaque pigments, fairly permanent to light. Acids cause the color to become more blue in hue, owing to their dissolving out the chrome yellow. Alkalies turn it orange, owing to their combined action both on the blue (changing this to a reddish-brown) and on the yellow (turning this orange). Sulphurous gases or sulphur darken the chrome greens considerably, if lead is present, as Chrome Yellow.

Lyes dissolve out the Chrome Yellows, leaving a residue of unchanged Emeraude Green (Oxide of Chromium) if this pigment was used, and change Prussian Blue to brown color (formation of iron hydroxide) if this blue was used in the mixture with chrome yellow. In order

to test for Prussian Blue, add to the lye solution an excess of hydrochloric acid and a drop of iron chloride, which should produce a deep blue color, if Prussian Blue was used as a constituent of the Chrome Green.

Chrome Yellows can also be detected by treating the Chrome Green with sodium sulphide resulting in the formation of black lead sulphide.

Gamboge and certain yellow or green lake pigments will yield yellow (or green) solutions in alcohol, when used as ingredients of Chrome Greens.

As pigments the Chrome Greens when consisting of mixtures of Prussian Blue and Chrome Yellow are only desirable as oil colors and then not to be considered thoroughly dependable for permanency. They are seldom used as water colors and not at all adaptable to fresco or other techniques. Their use as pigments dates from the early nineteenth century.

CHROME YELLOWS

Chrome Lemon, Chrome Yellow light, medium, and deep, Chrome Orange, Chrome Red, Paris Yellow, Kings Yellow, Jaune de Chrome, Giallo di eromo, Amarillo de eromo, Chromgelb

The pure rich chrome yellow hue is *neutral lead chromate*— $PbCrO_4$; the paler tints and lemon or citron chocolates are mixtures of *lead chromate* and *lead sulphate*, the orange hues are *basic lead chromate*— $PbCrO_4 \cdot PbO$.

The Chrome Yellows (neutral lead chromate) are all obtained as precipitates by the addition of a solution of a soluble lead salt to a solution of a soluble chromate or bichromate. Ordinarily a solution of lead acetate is brought together with a solution of potassium chromate or bichromate, yielding a precipitate of Chrome Yellow. This must be thoroughly washed free of the potassium acetate, which is formed and stays in solution. After

this the color is then dried at not too high a temperature. In order to obtain a uniform and brilliant product the temperature of the solutions during precipitation must be carefully regulated and great technical experience is required, as the resultant hue of the precipitate may otherwise vary considerably.

If during precipitation of the lead chromate, addition of the proper quantity of sulphuric acid is made, paler lemon or citron hues will be obtained. Alum and Blanc Fixe (BaSO_4) are also employed in making the paler Chrome Yellows.

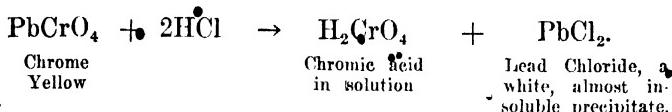
By treating yellow lead chromate with a weak solution of sodium or potassium hydroxide (caustic soda or potash), which removes some of the chromate radical of the lead chromate, basic lead chromate, orange yellow to orange red in hue, will be formed. *Chrome Orange* and *Chrome Red*, $\text{PbCrO}_4 \cdot \text{PbO}$, can also be obtained by precipitation from solutions of lead acetate, litharge and neutral potassium chromate; sometimes, also, with addition of caustic potash to yield the deeper, redder hues.

The Chrome Yellows are very strong toning colors, if chemically pure are reasonably permanent to light, showing a tendency to darken somewhat, becoming brownish in hue, especially noticeable when used as a Tempera or Water Color. Like all pigments containing lead, sulphurous gases convert the lead to black lead sulphide. For fresco and stereochromy only the Orange Chromes are practical as the Yellow Chromes would be rapidly changed to orange hues by action of the free alkali.

The Chrome Yellows are very opaque and dry well as oil colors. As oil colors, especially if protected by a strong film of varnish, the Chrome Yellows are reasonably permanent. However, when mixed with pigments of organic origin, especially those which themselves are prone to oxidize, they show a tendency to undergo reduction, that is, loss of oxygen by their chromate radi-

cal, yielding the green or lower oxide of chromium.

Hydrochloric acid decomposes Chrome Yellow yielding a solution, reddish yellow in color (free chromic acid) and a residue of white lead chloride:



The diluted solution of reddish-yellow chromic acid, if alcohol be added, will turn green in color upon warming, and produce agreeable aldehyde odor, resembling the smell of apples.

The white precipitate of lead chloride will dissolve in an excess of hot water, in which the presence of lead can be detected with sodium sulphide (formation of black lead sulphide).

Lyes also decompose Chrome Yellows with formation of yellow colored solutions of the alkali chromates. Ammonia dissolves Chrome Yellows yielding a yellow solution.

Caustic soda, not in excess, changes Chrome Yellows to orange color. Heated with carbon, Chrome Yellow is converted into metallic lead.

Impure pigments containing free sulphur or certain sulphur compounds, such as the sulphides, will darken the Chrome Yellows to a dark brown or gray (formation of black lead sulphide). For this reason they are incompatible with impure Ultramarines, Vermilions, Lithopone White, or Cadmium Yellows. When colors are required in admixture with yellows, pure zinc yellow, lemon or strontian yellow, barium chromate or the cadmiums should be used, as these contain no lead.

Kings Yellow is an especially brilliant pale variety of Chrome Yellow, sometimes also mixtures of Chrome Yellow and Zinc White; or for water color, Cadmium Yellow and Zinc White. The yellow sulphide of arsenic also

appears sometimes under the name King's Yellow, but is more commonly known as *Orpiment*. In recent years Orpiment has become obsolete as a pigment.

Chrome Yellow was discovered about 1797 but evidence of its use as a pigment does not appear until early in the nineteenth century.

CLAY

China Clay, Kaolin, Modeling Clay, Porcelain Clay, Tonerde, Fuller's Earth, Kieselguhr, White Bole, Pipe Clay

Principally *Hydrated Aluminum Silicate*— $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot 2\text{H}_2\text{O}$

The best varieties of clay for use in the fine arts are imported from England. Clay is a natural product found generally in beds of varying thickness, the prevailing colors being white, yellow, brown and red. These colors are due to the presence of iron, manganese, copper or other metallic oxides. The Ochres, Umbers and Siennas are clays colored with oxides of iron and manganese. *Fuller's Earth*, *Kieselguhr*, is a purer variety, being forms of silica and silicate of alumina, diatomaceous in nature. When pure, the China Clay is a fine white, amorphous powder, the chief characteristics of which are its plasticity and slight adhesive quality, its greasy feel and lustre. It is quite insoluble in water, dilute acids and alkalies and only slightly affected by heat. When strongly heated, the Clays become quite hard, due to the loss of moisture and combined water. This property is utilized in the manufacture of Pottery, Porcelain, China, Bricks, cte. The finest China Clays are generally known as *Kaolin*, which is its Chinese name. Prior to the discovery of the China Clay deposits in England and other countries, the best kinds of white pottery were imported from China, hence its name China Clay and the pottery made of the same became to be known as China.

Modeling Clays (*Plastic Clays*) are especially selected clays (*Rotten Granite*) yielding a stiff paste with water and consist exclusively of mixtures of pure aluminium silicate and silica. When foreign bodies, especially lime and sand are present, according to the amount of these in admixture, the plasticity of the clay is reduced.

As a pigment China Clay is quite permanent, resisting perfectly exposure to light and atmosphere for any length of time. Owing to its lack of body and transparency when ground in oil, it is more advantageously used as a carrier or base in the preparation of lake colors and as an inert extender or filler, in the heavy paint trade. It is also used to keep pigments of heavy gravity in suspension.

COAL-TAR COLORS AND DYES

The large group of artificial organic dye-stuffs, which only since the middle of the nineteenth century, have been synthetically produced from the chemical constituents of coal-tar, formerly considered a waste by-product of destructive or dry distillation of soft coal in the manufacture of coal gas, ammonia liquor, tar and coke, have almost in recent years displaced the natural organic dyes. These latter represent color extracts of organic and animal origin, such as Carmine from the dried Cochineal insect, Yellows from the Quercitron Bark, Alizarin from the Madder Root, etc. The natural dye-stuffs were known and used as dyes and pigments from earliest classical times. Pliny in his "Naturalis Historia," A.D. 77, made considerable mention of them.

Coal-tar is a brownish-black, oily, viscous fluid, colored by suspended carbon and of exceedingly complex composition. More than a hundred substances are more or less accurately known and identified in it. These neutral, acid and a small quantity of basic substances are obtained individually from the coal-tar, partly by fractional

distillation and partly by chemical means. The crude tar is distilled usually into four fractions:

Distillate	Distilling Temperature	Constituents of the Fraction
Light Oil or Crude Naphtha.....	up to 170° C.	*Benzene (Benzol) and homologues.
Middle, or Carbolic oil	170°-230° C.	Carbolic Acid and Naphthalene.
Heavy, or Creosote oil	230°-270° C.	Constituents not usually separated.
Anthracene oil	above 270° C.	Anthracene.
Pitch.....	residue in still, consisting mostly of carbon.	

* Benzene C_6H_6 (Benzol) from coal-tar should not be confused with Benzine a derivative of Petroleum.

The oily distillation products, which alone are valuable to the color manufacturer, form about 48 percent of the total distillates, comprising essentially the following hydrocarbons:

Benzene (Benzol) C_6H_6 from which Aniline and many dyes and drugs are prepared, and its homologues Toluene (Toluol) $C_6H_5CH_3$; Xylene (Xylool); Phenols; Cresols; Naphthalene $C_{10}H_8$ sold ordinarily as moth-balls and the starting point for synthetic Indigo and Anthracene $C_{14}H_{10}$ from which valuable dyes such as Alizarin and Indanthrene are made. A very few of these tar products are directly used for color making, most of them being converted by chemical processes into derivatives, suitable for reactions employed for producing the coloring matters.

Unfortunately the greater majority of the inconceivable number of colors obtained as dyes from the coal-tar derivatives cannot be practically used to manufacture lake pigments, owing to their exceedingly fugitive character when exposed to light, which is likewise true of the lake colors made from them. Some of the true aniline colors, as Mauve (Aniline Violet), Fuchsine (Aniline

Red), **Methylgreen**, **Aniline Blue**, the **Eosines**, many yellows, etc., on account of their great brilliancy, are in demand and used despite their fugitiveness, some disappearing entirely if exposed to direct sun light but for a short time.

Aniline Colors do not comprise the entire group of Coal-Tar Colors as is often erroneously supposed, but represent only a small group of one of the many already mentioned derivatives of the coal-tar, having as their base **Aniline** or its related compounds.

In the year 1856 Sir William Perkin discovered a beautiful violet compound, **mauve**, while experimenting with aniline. During the next few years he established the manufacture of mauve on a commercial basis. This proved to be the starting point for a great industry for the preparation of thousands of different colors of almost every conceivable hue by synthetic processes. Some of the artificial dyes are identical with those obtained from natural sources, being in many instances more brilliant and permanent than the original.

The majority of coal-tar dyes are soluble in water and must be precipitated on a neutral base or carrier, to form an insoluble lake pigment. Alcohol or water extracts some dyes from lake pigments, or from pigments which have been adulterated with dyes, this forming a simple test for their detection.

When some of the more permanent lake pigments (alizarin, etc.) are used in admixture with such colors as the Burnt Ochres, Bt. Siennas and Bt. Umbers, etc., they can not be looked upon as adulterants, but are safe combinations producing a more brilliant and colorful pigment.

Some coal-tar colors, which are entirely free from poison or have no physiological effect on the human system and which before use must have the approval of governmental bureaus are frequently used as coloring mat-

ter in food stuffs, viz., confectionery, ice cream, beverages and also in cosmetics. The coal-tar products are used principally as dyes and for the manufacture of color pigments. There are however, any number of other purposes for which they are used.

COBALT BLUE

Bleu de Thenard, Kings Blue, Bleu de cobalt,
Bleu Cobalto, Azul de Cobalto, Kobaltblau.

Principally the *Oxides of Cobalt*—CoO—and *Alumina*—Al₂O₃—with occasionally presence of phosphoric acid; arsenic acid or Zinc Oxide, to yield different hues.

According to the method employed in its manufacture Cobalt Blue is a mixture of either oxide, phosphate or arsenate of Cobalt with aluminum oxide yielding a deep rich blue tending toward violet. Optically Cobalt Blue reflects a considerable amount of green and violet light, in consequence of which it acquires a decided purplish hue when examined by artificial light, particularly by gas or candle light.

The usual Cobalt Blues of violet hue, are compounds of cobaltous oxide and aluminum oxide. Variable amounts of zinc oxide to Cobalt yield a pure greenish-blue, the hue of which varies according to the quantity of Zinc Oxide present. By heating at high temperatures an intimate mixture of Aluminum Oxide, or Alumina, (Aluminum hydrate) with Cobalt carbonate, phosphate, or arsenate, the pigment Cobalt Blue is obtained. Alumina in excess will produce lighter tints.

The Cobalt Blues are used safely in all techniques, absolutely permanent to light and air, non-poisonous, with little covering power and can be mixed with all other pigments without affecting them in any way, or being altered thereby themselves. Weak acids or alkalies do not affect Cobalt Blues, likewise they are impervious to sulphurous gases.

Ultramarine Blues are sometimes offered as cheaper substitutes for the Cobalt Blues, but can be easily recognized by treating with acids (evolution of H_2S).

Like all cobalt compounds, when fused with borax on the loop of a platinum wire even in small quantities a deep blue glass-head is formed.

Cobalt Blue appeared as a pigment in the early nineteenth century.

COBALT GREENS

Rinmann's Green, Zinc Green, Vert de Cobalt,
Vert de Zinc, Vert de cobalt, Verde di cobalt,
Verde de cobalto, Kobalt Gruen

Essentially a compound of *Cobaltous Oxide*— CoO —with *Zinc Oxide*— ZnO .

These greens are prepared in similar manner to Cobalt Blue, the compound being formed when cobalt oxide and zinc oxide, in intimate mixture, are heated at high temperatures. The paler tints require consistently greater amounts of zinc oxide.

The genuine Cobalt Greens are absolutely permanent, semi-transparent, the deeper shades being more transparent, dependable and safe in all techniques and in mixtures with other pigments will not alter or themselves become altered by these, will not decompose at moderately high temperatures.

Hydrochloric acid dissolves Cobalt Greens to a rose-red solution (Chlorides of Cobalt and Zinc). The deep blue glass-head, characteristic of Cobalt compounds, will be produced when fusing Cobalt Green with borax on a platinum wire.

Some less expensive pigments are found on the market under the name Cobalt Green, which are usually mixtures of Ultramarine and Zinc Yellow. These are not however, as safe; as substitutes obtained by mixtures of Cobalt Blue and Cadmium Yellow or other safe Yellows

Emeraude Green (hydrated oxide of chromium) or oxide of chromium opaque having greater color value and of equal permanency find greater favor as a pigment.

The Cobalt Greens were discovered by the Swede, Rinmann, during the end of the eighteenth century.

COBALT VIOLETS

Cobalt Violet Light, Cobalt Violet Deep, Cobalt Red, Violet de cobalt, Violetto cobalto, Cobalto violeta, Kobaltviolet

Anhydrous Cobalt Phosphate— $\text{Co}_3(\text{PO}_4)_2$.

This absolutely permanent and dependable violet hue pigment, transparent, with but little tinting power or brilliancy, is adaptable to all techniques. It is not acted upon by acids or bases and heat will not destroy the Cobalt Violets, as is the case with the great number of more brilliant organic violet lakes, such as Mauve, Purple Lake, etc. Cobalt Violet is insoluble in the ordinary solvents and is not discolored by sulphurous gases.

By precipitating a solution of any soluble Cobalt salt with a solution of Disodium Phosphate ($\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$) thoroughly washing and drying the precipitate and then heating to a high temperature, the yield will be Cobalt Violet.

Pigments consisting of cobalt and magnesium oxides, prepared at high temperatures to yield more reddish hues are sometimes called Cobalt Red. When alumina is present a more purplish hue is obtained. These pigments are quite permanent and possess complete stability in the different vehicles employed in the various techniques. Likewise, the Cobalt Violet pigments consisting of cobalt arsenate, with sometimes small quantities of the phosphate present, obtained also at high temperatures, are of varying hues and share the permanent qualities of the Cobalt Violets already described.

Heated on the loop of a platinum wire with Borax, like all Cobalt compounds, the Cobalt Violets will yield a blue glass bead.

Cobalt Violets were introduced as pigments in 1859 by Salvétat.

COBALT YELLOW

Aureolin; Jaune de Cobalt; Kobaltgelb

This yellow crystalline compound salt of the metal Cobalt, *double Nitrite of Cobalt and Potassium*; has been described under Aureolin, with which it is synonymous in chemical and physical properties.

COLOGNE EARTH

This color is synonymous with Vandyke Brown (which see).

CORK BLACK

Receives its color principally from Carbon, in form of a charcoal.

This pigment is a variety of carbon black obtained by charring cork. It resembles Blue Black (which see) in all physical and chemical properties, however, has more tinting strength than most other charcoal blacks.

CRAP LAKES

(See Madder Lakes)

CREMNITZ WHITE

Bianco Cremnitz, Blane de Cremnitz veritable,
Blanco de Crems, Kremserweiss

A basic carbonate of lead— $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$.

This pigment derives its name from a certain quick process for the precipitation of White Lead, originating at Kremnitz in Bohemia. The White Lead obtained by this method is in all chemical respects similar to the well-



known Dutch process White Lead and the more recent White Leads obtained by various new processes. Physically it differs, however, from most other White Leads in that it is of decided crystalline structure, exceedingly hard, differing considerably in this respect from the more amorphous, soft Flake Whites. Cremnitz White will in consequence of its structure, yield a surface with fine grain, to which subsequent applied colors will adhere well. It, therefore, forms an ideal pigment for the laying of foundations, giving a decided "tooth" on which to paint.

Cremnitz White possesses as a pigment all the best qualities of the White Leads, viz., good color, opacity and permanency to light and pure air. It is very sensitive to sulphur, sulphuretted hydrogen, sulphides, and sulphurous gases, in their presence turning brownish to black (formation of black lead sulphide). If protected by an oil film and coat of varnish this reaction is not likely to occur. There being no such protective vehicle or varnish used in fresco, mineral painting (Stereochromy) or water color techniques, eliminates Cremnitz White from use in these.

Impure Cadmium Yellows, Quicksilver Vermilions, Ultramarines or other pigments containing free sulphur or dangerous sulphur compounds, in comixture with Cremnitz White will produce discoloration. When these pigments are pure this reaction is not evident. Mixtures with pigments of vegetable or animal origin are best regarded as of uncertain stability, because the organic pigments in mixture with the white lead suffer decomposition or reduction.

For further chemical and physical properties refer to White Lead, with which Cremnitz White is synonymous.

CYANINE**Leitch's Blue**

A mixture of Cobalt Blue and Prussian Blue.

This semi-transparent color is practically permanent, the Cobalt Blue constituent of the admixture seeming to protect the Prussian Blue from change, by absorbing some of the active (actinic) rays of light. Less satisfactory mixtures of Ultramarine Blue and Prussian Blue are sometimes also offered as this color.

Cyanine Blue can only be used in oil, tempera and water color techniques, and not in fresco or stereochromy owing to the decomposition of the Prussian Blue constituent in presence of alkalies. (See Prussian Blue and Cobalt Blue for chemical properties.)

CYPRIUS GREEN

A very permanent lake color of individual brilliant and rich blue-green hue. The coloring principle being precipitated on a transparent base of alumina, lends the pigment particularly useful as an overglazing color.

Cyprius Green is adaptable only in oil and water color techniques.

DAVEY'S GRAY

A color prepared from silicious earth, either clay or slate used more extensively in England as a pigment, where it was originally introduced by Mr. Henry Davey. The color is permanent, semi-transparent and used principally in mixture with other colors to reduce the tones, yielding shades clearer and more translucent than when blacks are employed for this purpose.

Admixtures of Cobalt Blue (or Ultramarine) Lamp Black and Zinc White are sometimes offered as Davey's Gray, and as such are also permanent and durable.

DELFT BLUE

Delft Blue No. 1 deep, Delft Blue No. 2 light

This semi-opaque deep hue is obtained by admixture of Indigo and Ultramarine; is not, however, as permanent to light as when the same is obtained from Prussian Blue (or Antwerp Blue), Lamp Black and Ultramarine.

DRAGON'S BLOOD

A deep brown-red colored resin obtained principally from one of the rattan cane palm trees, *Calamus draco*, found native in Eastern Asia. The ripened fruit of the tree is covered with a deep red, very friable resin, which is collected. This resin also exudes from wounds, made for this purpose, in the bark of the tree. After sifting out any impurities, the resin is heated either by placing in the sun, or in boiling water, and moulded into thin rolls, then wrapped in reeds or palm leaves and in this condition, is placed on the market.

The best qualities of Dragon's Blood are of deep red, nearly blackish color, homogeneous, inodorous, with sweetish taste, nearly opaque; however, in thin slices it is of transparent deep crimson color. As a pigment it is exceedingly fugitive to light, a very poor drier in oil and the color is destroyed when in mixture with certain metallic pigments, such as White Lead, etc. Dragon's Blood is soluble in alcohol, benzol, chloroform, alkalies, in most fixed and volatile oils, and sparingly soluble in turpentine or ether. At one time it was used in pharmacy, its astringent properties being valued medicinally. It is now used principally as coloring for lacquers, varnishes, toilet articles, etc., but seldom as an artists' color.

Dragon's Blood was called "Cinnabar" by the ancients and received mention by Pliny in his "Naturalis Historia," A.D. 77.

EGYPTIAN BLUE

A double silicate of calcium and copper— $\text{CuO} \cdot \text{CaO} \cdot 4\text{SiO}_2$.

A pigment known and used by the early Egyptians from the time of the fourth dynasty and throughout the Roman Empire until the seventh century, when its manufacture and application as a pigment seems to have ceased, not appearing on the palette of the artist during the many following centuries. Egyptian Blue is soluble in boiling hydrochloric acid, which solution if treated with an excess of ammonium hydroxide, shows the deep blue colored solution characteristic of pigments containing copper.

EMERALD GREEN

Paris Green, Vert Paul Véronèse, Schweinfurt Green, Mitis Green, Veronese Green, Cenere verde, Vert cendre, Verde ceniza, Mineral Green, Swedish Green, Scheele's Green

Cupric Aceto Arsenite— $(\text{CuOAs}_2\text{O}_3)_3 \cdot \text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$

Emerald Green is an aceto-arsenite of copper, varying somewhat in composition according to the process employed in its manufacture. In 1814 while experimenting to improve Scheele's Green; (*copper arsenite*) (also called **Mitis Green** and **Veronese Green**) named after its discoverer, the eminent Swedish chemist Scheele in 1778, the much more brilliant **Schweinfurt Green** (**Emerald Green**) was developed at the color works of W. Sattler at Schweinfurt, from which it receives its name.

Scheele's Green, **Mineral Green**, **Swedish Green**, *Cupric Arsenite*— CuIIAsO_3 has similar physical and chemical properties to Emerald Greens; is, however, not as permanent to light, is non-crystalline in structure and being far inferior in hue has been entirely displaced by the Emerald Greens. **Scheele's Green**, when heated with sulphuric acid, will not develop the characteristic vinegar

odor, evidenced when Emerald Green is treated in like manner.

Soon after the discovery of Emerald Green many methods were developed to produce these greens and altho they are all based on the use of *Verdigris*, or *copper sulphate* (*Blue vitriol*), *Acetic acid* (*Vinegar*) and *white arsenic* as the essential materials, a great number of varying hues are obtained according to the process employed. The resultant color in all cases must be thoroughly washed in order to prove dependable as a pigment. In hue, Emerald Green, is nearly normal green, verging on blue-green.

Emerald Green is a practically permanent color in oil, proving safe in admixtures with most all other dependable pigments, Ultramarines and Vermilions being perhaps the only exceptions as in commixture with these the black sulphide of copper may be formed.

Emerald Green should never be used with the Cadmiums. In this mixture discoloration quickly ensues and the paint becomes black.

Most organic lake pigments are readily decomposed in mixture with Emerald Green.

When protected by a strong film of varnish, impure air containing sulphur gases, cannot attack the Emerald Green to form black copper sulphide, which is noticeably evidenced when used as a water color.

Emerald Green is entirely soluble in boiling hydrochloric acid or nitric acid or ammonia, yielding no insoluble residue (*Barytes*, *Gypsum*, *Chromes*, etc.) and should show no precipitation upon addition of barium chloride to the clear solution. When treated with *acid potassium ferrocyanide*, Emerald Green will discolor brownish. Hydrogen sulphide gas— H_2S —as also sodium sulphide, will decompose the copper greens, with formation of black copper sulphide.

A small amount of Emerald Green dissolved in hydro-

chloric acid, if a small piece of metallic zinc be added, will evolve the *extremely poisonous* gaseous Arsine (AsH_3), recognized by the characteristic garlic-like odor. Use extreme caution if this test be made.

Emerald Green is a very poisonous pigment. The commercial Paris Green, *Cupric Arsenite*— CuHAsO_3 —also a compound of Copper and Arsenic, is a powerful insecticide and very inferior as a pigment.

Ammonium hydroxide dissolves Emerald Green to a deep blue colored solution (characteristic test for all copper pigments).

Emerald Green owing to its sensitiveness towards alkalies is not adaptable to mineral painting or fresco techniques.

EMERAUDE GREEN

Verde smeraldo, Vert emeraude, Verde esmeralda,

Hydrated Oxide of Chromium— $\text{Cr}_2\text{H}_4\text{O}_5$.

This exceedingly permanent and unalterable green pigment is one of the most useful and safe colors to be found on the artists' palette for all techniques. Its chemical and physical properties are fully described under *Oxide of Chromium, Transparent*, with which pigment it is synonymous.

FLAKE WHITE

Blanc d' Argent, Blanco de plata, Bianco argento, Bleiweiss,

Basic Carbonate of Lead— $2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$.

A variety of White Lead obtained by one of the more recent "quick processes," which are improved developments over the original Dutch process (see White Lead). It yields a decided amorphous, flaky pigment, lacking the more crystalline structure of the Dutch and Cremnitz White Leads.

Some artists' Flake Whites are an especially opaque

variety of Zinc White, altho not having quite the degree of opacity of the lead white, have the redeeming quality of retaining their more brilliant white color, when exposed under conditions which would considerably alter the appearance of lead whites. Such a condition, under which the lead whites and pigments containing lead, are subject to change, is in the presence of sulphurous gases, or in admixture with impure pigments having excess of free sulphur, or sulphides.

FLESH OCHRE

Oere de chair, Oeria di carne, Oere color de carne,
Fleischocker,

A variety of natural ochre receiving its color from the presence of iron hydrates and oxides. Like all native ochre pigments, it is an absolutely dependable and permanent color for use in all techniques, with fair degree of opacity. In mixtures with organic pigments, such as the lake colors there is a slight tendency to decompose the latter, thereby destroying the color. Physical and chemical properties are fully described under *Ochres*.

GAMBoge

Gambogium, Gummigutt, Gomaguta, Gomme-gutte, Gomma gutta, Goma gutta,

A semi-soluble gum-resin produced by several species of Garcinia tree found native of India, Ceylon and Siam. The best varieties are usually offered in pipes, or cylindrical rolls of varying length, about one and one-half inch in diameter, very brittle, of orange color and covered with a yellow powder. The gum resin exudes as a milky liquor from incisions in the bark of the tree, gradually setting hard. It is then collected, melted and poured into moulds of hollow bamboo cane. The powdered gum Gamboge is often adulterated with starch, flour or even

powdered resin, etc. Gamboge gives a cloudy emulsion when dissolved in water, having no odor, but of very acrid, bitter taste. It is poisonous, its strong purgative properties being used medicinally.

Gamboge is a mixture of about 20 per cent. water-soluble gum and about 80 per cent. alcohol, ether, chloroform, etc., soluble resin. This resin has properties of an acid, forming compounds with soda, lime or other bases and is the active color principle of the Gamboge.

Gamboge gradually fades exposed to light and bleaches under exposure to strong sunlight, however, recovering its color when placed in the dark, which is also characteristic of the coloring matter of many vegetable oils. Although not affected by sulphur compounds, Gamboge is darkened by ammoniaeal vapors and alkalis, is soluble in alcohol, ammonia and partially in ether and has no chemical action on other pigments, however undergoing decomposition in admixture with certain metallic pigments, such as White Lead, Chrome Yellows, Verdigris and some native raw earths. High temperatures will also destroy this color. Gamboge is dissolved by acetic acid and turns deep orange red with caustic potash.

With Prussian Blue or Indigo a wide range of clear and rich greens is obtained, of which extensive use is made in water color painting (*Hookers Green No. 1 light, Hookers Green No. 2 deep and Prussian Green*). These greens are not permanent to direct sunlight, owing to their content of Gamboge.

As an oil color Gamboge is greatly enhanced in permanency and durability by the addition of a small amount of copal resin or wax. The partial solubility of Gamboge in most ordinary solvents, renders the restoration of aged paintings very difficult.

The early Flemish oil-painters used Gamboge and during the 17th century it was employed in making the

famous embossed letters of golden hue, for which Amsterdam was noted.

GERANIUM LAKE

Laque géranium, Lacca geranio, Laca de geranio,
Geraniumlack,

This color will be best understood if reference is made to the listing of "Lake Colors," under which all lake colors are fully described as a class.

Soon after the discovery of Eosin dye, in 1876, many lake pigments were introduced having this powerful and brilliant, but exceedingly fugitive dye as the coloring principal on various bases. The Geranium Lakes used principally in the fine arts are precipitated on the transparent alumina hydrate base. This color when produced from fugitive dyes, such as Eosin, Erythrosine, etc., fades in very short time and should not be used, even if only a fair amount of permanence is required.

The development of the coal-tar dye industry has in recent years fortunately made it possible to produce a Geranium Lake, which is of good permanency. Some artists' Geranium Lakes have been developed from this new color to yield a pigment, which can be considered practically permanent under exposure to light, and unaffected by alkalies. The artist desiring to use Geranium Lake should first acquaint himself with the permanence of the color from the respective color manufacturer.

There are two usual commercial hues of Geranium Lake, that having a decided bluish under-tone and that tending towards the yellowish.

When made of permanent constituents Geranium Lake, like all Lake Colors, is best used as an overglaze color and should not be put in admixture with any of the raw earth pigments, *i.e.*, Raw Sienna, Umbers, Ochres, etc., and with certain metallic pigments, *i.e.*, the Chrome Yellows, Chrome Greens, White Lead, etc. with which colors

decomposition is prone to occur. Mixtures with safe colors, such as other permanent lakes; chemical pigments, such as Cobalt Blue, Cobalt Violets, Opaque and Transparent Oxides of Chromium, the calcined native earth colors, such as Bt. Sienna, Bt. Umber, Light Red, etc. are dependable.

Geranium Lake finds use principally in oil and water color techniques, but is readily displaced by the more permanent and brilliant, dependable Alizarin Madders.

GRAPHITE

Blacklead, Plumbago,

An allotropic crystalline form of Carbon.

Graphite is obtained from natural deposits, the most important being found in Ceylon, Siberia, England, Bohemia, and New York. Graphite usually varies in purity 60 per cent. to 90 per cent. Carbon content, the remaining constituents being mostly silica and clay. Graphite differs from other forms of Carbon, in being very soft and of very high kindling temperature. That used as a pigment has a gray-black tint, with metallic lustre, is quite opaque, unctuous to the touch and amorphous in structure.

With white (Zinc White) delicate neutral grays are obtained. Graphite when prepared free from any foreign matter, is an absolutely permanent color, having no effect on any color in admixture and has very little tinting strength.

Alkalies or acids do not react with this pigment and it is insoluble in all ordinary solvents.

In oil Graphite dries very slowly, and if applied in thick layers, a skin forms on the surface, underneath which the color will remain soft for years and if over painted with colors drying hard such as zinc, red lead, umbers, etc., cracks are bound to result in the painting.

As a pigment Graphite is of no importance, being used principally in the manufacture of lead pencils. For this purpose the selected Graphite is thoroughly cleaned of any impurities and mixed with clay. The varying degrees of hardness are secured by altering the proportion of clay and the temperature under which the moulded lead for the pencil is subjected, after which it is encased in cedar wood and given the finish of the well-known lead pencil.

There also appears as a pigment, **LEAD BLACK** the black sulphide of lead made artificially or found native in the beautiful lead ore, *Galeyna*; which is however unimportant and seldom used as a pigment, being prone to decompose or oxidize to form lead sulphate, thereby changing the color to a brownish-gray hue.

GREEN LAKES

Green lake light, medium and deep., Laque vert,
Lacea verde, Laca verde, Gruenerlack,

This pigment has no definite composition, being made by different colormen from varying constituents. There are many other commercially valuable and reasonably permanent green lakes to be had, which are usually adaptable to the specific purpose, for which they are intended. Namely the pigment is specially made, by altering both the color principle and the base on to which the color is fixed to form the lake, to yield a product that will be acid, alkali, or gas resistant, non-bleeding in oil or water, transparent or opaque and permanent to light, or to have any other physical or chemical property, that may be required.

Mixtures of Zinc Yellow and Prussian Blue with Alumina are sometimes offered as reasonably permanent and safe Green Lakes. Those produced by admixture of such colors as Dutch Pink, Italian Pink or any other

of the very many fugitive organic dye-stuff yellow lakes with Prussian Blue are not to be considered safe, some fading in direct sunlight under exposure of but a few hours. The artist must rely on the recommendation of the color manufacturer to supply a Green Lake, which will meet the requirements of the technique in which the pigment is to be used.

GYPSUM

Terra Alba, Mineral White

Hydrated Calcium Sulphate— $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

Gypsum occurs native principally as the *true gypsum* with two molecules of water of crystallisation— $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ —and as the mineral *anhydrite* in rhombic crystals— CaSO_4 .

Large strata and sometimes whole mountains are formed of deposits of either or both minerals in many parts of the world, and are thought to have been formed as deposits from evaporation of the one time inland seas or lakes. Gypsum is also made artificially, being sometimes a by-product in certain operations. When found native in an impure dense condition, it forms the so-called *gypsum-spar*, or when in a granular crystalline form, often more or less colored in a variegated manner, is known as *alabaster*.

Gypsum is a very soft mineral, easily ground and when pure is of good bluish-white color, lighter in gravity than barytes or white lead, but heavier than china clay or zinc white. It has but little opacity when ground in oil; working well with water, in which it is slightly soluble. For this reason it is not good for outside work, especially marine work in heavy-paints.

As a base for lake pigments it is neutral in its properties and can be mixed with all other pigments without affecting them or being affected by them. It is one of the most permanent pigments unaffected by exposure

to light and air. Gypsum is soluble in hot hydrochloric acid, without effervescence.

To test for Gypsum as an adulterant, boil a sample of the color in water, filter, and to half of the filtrate add hydrochloric acid and then upon the addition of barium chloride, BaCl₂, an insoluble white precipitate of barium sulphate, BaSO₄, will be formed in presence of the sulphate radicle—SO₄—contained in the gypsum—CaSO₄. To the other half of the filtrate, if gypsum is present, a white insoluble precipitate of calcium carbonate—CaCO₃—is formed upon the addition of sodium carbonate—Na₂CO₃.

When heated between 100° and 204° C. Gypsum loses a portion of its water of crystallisation and forms a white powder known as *Plaster of Paris*. (Calcium Sulphate—2CaSO₄.H₂O) which has the property of again combining with water, setting to a hard solid mass accompanied by a slight increase in volume. Of this property, important use is made for moulding and casting purposes and for the making of *mortar* etc.

Stucco is a mixture of Plaster of Paris and rubble with a solution of glue, instead of water. When Gypsum is heated above 204° it loses all its water of combination and becomes *anhydrous calcium sulphate*—CaSO₄—which is then no longer able to take up water of crystallisation again and will not set hard with water, it is then said to have been killed.

Gypsum is one of the white earth pigments used from earliest times and in mediaeval times, was already applied, as a base for certain lake colors.

HARRISON RED

This permanent brilliant vermillion hue pigment is made from a product of one of the large dye industries of Germany and originally introduced under the name of Harrison Red in honor perhaps of the eminent American artist, Birge Harrison.

It has great tinting power and will not bleed in oil, in which it is a very slow drier. When used properly, it is a valuable substitute for most vermilions, being more dependable in permanency to light than these and can be safely modified in hue by admixture with the Alizarin Madders.

Being a Lake Color Harrison Red has the usual chemical and physical properties attributed to this class of pigments.

HOOKERS GREENS

Hookers Green I light, Hookers Green II deep

Prussian Green, Verde di Hooker, Vert de Hooker, Verde de Hooker, Hookersgruen

Mixtures of Prussian Blue and Gamboge in varying proportions to give light, medium and deep hues of a rich transparent green color, used almost exclusively as a water color, sharing the lack of permanency of the Gamboge constituent and possessing the chemical and physical properties of both constituents. The deepest hue is *Prussian Green*.

In oil color similar hues are obtained by mixing Prussian Blue with the Alizarin Yellow Lakes, Cadmium Yellows, Zinc Yellow or Lemon Yellow.

The colors receive their name from the artist who first introduced their application as pigments.

INDIAN LAKE

Lac Lake

This deep red organic lake pigment is today very little in demand owing to its lack of brilliancy and permanency, being satisfactorily replaced on the artist's palette by the far more safe, brilliant and permanent Alizarin Madders.

Indian Lake is, however, a very old pigment, known and used as early as the thirteenth century and met with on old manuscripts

The coloring principle (lac dye) of this lake pigment is the product of *Coccus lacca*, an insect, which lives on species of trees, all of which have very gummy or resinous sap, principal among which are the species *Butea*, *Ficus* and *Croton*. The gravid female insect punctures the bark of the tree and becomes enclosed in the exuding juice, which hardens into resin. The young develop in the body of the dead mother insect and crawl out leaving a red coloring matter in the resinous deposit. This red dye (Lac dye) is then obtained from the resinous mass, which mass when broken off the twigs of the tree constitutes what is known commercially as stick-lac.

INDIAN PURPLE

A moderately permanent semi-transparent color made usually by precipitating Madder Lake in the presence of Ultramarine Blue. It has little brilliance and can be readily duplicated in hue on the palette of the artist.

When produced by mixtures of Antwerp Blue and Vermilion tinted with Carmine, a less permanent and brilliant product is obtained.

INDIAN RED AND RED IRON OXIDES

Rouge indien, Rosso indiano, Rojo indiano, Indischrot, Caput mortum, Coleothar, Rouge, Iron Oxides, deep and violet, Persian Red, Tuscan Red, Pompeian Red, Venetian Red, Rouge de Venise, Rosso di Venezia, Rojo de Venecia, Venezischorf, Terra Pozzuoli

The basis of these colors is *Ferrie Oxide*— Fe_2O_3 .

Under this classification belong a great variety of red iron oxide pigments, from a light, bright red to a deep purplish-red hue, in which the active coloring principle is ferrie oxide. They are either native earths, such as the original Indian Red, Venetian Red, etc., in which case

they closely resemble the red ochres (see Ochres natural and calcined) or are artificially prepared products. In both instances they are thoroughly dependable and perfectly permanent pigments with considerable opacity and tinting strength.

The native mineral haematite (*Red Iron Stone* or *Blood Stone*) or red ochre, in which the ferric oxide occurs nearly chemically pure, containing about 95 percent, has been the source of supply for the natural red pigments from earliest classical and ancient times. The name Indian Red originated possibly from its original source, the Orient, particularly Persia, or perhaps from the American Indian who used the native red earths to color their wigwams and as body decoration.

The natural red iron oxides are mostly, very pure products, of dark hue and as such are equally as permanent and dependable as those artificially prepared.

The original Venetian Red, the lighter less purplish, more red in hue is a native product, but is now usually prepared artificially, representing sometimes mixtures of the lighter oxide with whiting or clay.

A great variety of hues are obtained by artificially manufacturing the red oxide pigments by two methods, *i.e.*, The *Dry Process* and the *Wet Process*, the deeper more purplish in hue being offered as Indian Red, the lighter more red in hue as Venetian Red and still paler and more brownish hue sometimes as Light Red; altho Light Red is usually understood to be a calcined variety of Yellow Ochre.

Ordinarily the Dry Process is used in making these pigments. It consists in the heating of *copperas* (*ferrous sulphate*— $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) to yield the pure *ferric oxide*— Fe_2O_3 . By regulating the temperature at which the calcination is carried on, as also its duration, the hue of the resulting oxide will vary from a bright red by moderated heat, to a deep purplish hue by white heat.

The lighter hues usually require a much more careful washing to free from the partly decomposed copperas. Many impure samples contain basic iron sulphates, which may be detected by moistening the pigment with water and heating to glowing in a test tube. The moisture, which condenses on the cooler wall of the test tube, should not turn blue litmus paper red.

The Wet Process usually utilizes by-products of iron compounds, which formally in great many instances were thrown away as useless, but today the iron is precipitated from solution and calcined; to yield, as in the Dry Process, the varying hues of iron oxide reds.

In the hydrated form, ferric oxide represents the active coloring principal of the native ochres, siennas and umbers, which when calcined give up their water of hydration to yield the red ferric oxide, changing thereby from a yellow or brown hue to a decided warm red hue, characteristic of which is Bt. Sienna from Raw Sienna.

When thoroughly washed, all the Red Iron Oxide pigments represent most dependable and perfectly permanent pigments for use in all techniques. They are indifferent to alkalies and more or less soluble in acids, the lighter hues do not resist acids as readily as do the deeper purplish hues. They are insoluble in water and alcohol. In mixture with other safe pigments they do not alter these or suffer any change in themselves. The Red Oxides are not altered by moderate heat and should not yield a tarry distillate on the walls of a test tube when heated to glowing. Zinc White or Permalba and Indian Red will yield most reliable flesh tints. Mixtures of Alizarin Madder and Red Oxides are offered as *Tuscan Red* or *Pompeian Red*. The Alizarin Madder in this mixture does not decompose as is likely when mixed with the native raw earths containing the hydrated iron oxide.

INDIAN YELLOW

Piuri, Purree, Jaune indien, Giallo indiano, Amarillo indian, Indischgelb

An impure magnesium and calcium salt of curanthic acid— $C_{10}H_{10}MgO_{11} \cdot 5H_2O$.

Genuine Indian Yellow is obtained from the urine of cows, which are fed principally upon mango leaves, which food stimulates the secretion of bile, the excess of which strongly colors the urine. The bright yellow urine is boiled down in earthen vessels, yielding a yellow mass, which is strained through a material, such as calico; formed into balls and put on the market in this shape. About two ounces of Purree is obtained daily from one cow producing about three quarters of a gallon urine. It is made almost exclusively at Monghyr in Bengal, by a tribe of people known as the Gwalas. The crude round balls of Indian Yellow about three or four inches in diameter, are of dirty greenish to brown color externally and internally of bright yellow hue, with characteristic ammoniacal, urinous odor and non-poisonous.

The coloring principle of Indian Yellow is the salt, magnesium euxanthate, which is not present alone in the natural pigment, but always associated with foreign mineral and organic matters. These impurities are responsible for the strong odor and dark brownish color of the impure pigment. This raw material, called Piuri, or in English Pufree, is first freed from the brown earthy crustation, then powdered and washed thoroughly in boiling water, until the water filtered from it comes off clear showing no brownish discoloration. This treatment removes a brown colored impurity and considerable of the odor is thereby lost. The pigment is then dried and used directly in this condition. When improperly purified the permanence of the color is considerably affected.

The genuine purified Indian Yellow is of a deep and rich translucent orange-yellow color, however, of questionable permanence as a pigment. In mixtures with other safe pigments it is not readily decomposed or acted upon by sulphur compounds. It is mostly used as a water color and oil color, in which latter it is a slow drier, but excellent as an over-glaze color. Being somewhat soluble in water it is not adaptable to fresco or mineral painting (stereoclytomy).

Composed chiefly of organic matter, genuine Indian Yellow leaves but little white ash when calcined. Dilute hydrochloric acid decomposes the pigment, destroying the color and precipitating white flaky euxanthic acid (in contrast to most of the yellow lakes which yield yellow colored solutions when treated in similar manner). Ammonium hydroxide added in excess to the acid solution yields a clear solution bright yellow in color, (yellow lakes in acid solution, usually precipitate Alumina or Tin hydroxide when ammonium hydroxide is added in excess to the acid solution).

The more modern Alizarin Yellow Lakes are in greater favor, when dependable substitutes for Indian Yellow are desired and are usually offered as Indian Yellow in lieu of the genuine product.

INDIGO

Indigo Carmine
Intense Blue, Indeo,

The principal coloring matter of genuine natural Indigo consists chiefly of *Indigotin*— $C_{16}H_{10}N_2O_2$.

Indigo is a product occurring in considerable quantities in a large number of different plants, principal of which is the species *Indigofera* (*I. tinctoria*) indigenous to India, Java and many other tropical countries. Bengal, India, is the principal source, although the finest variety is obtained from Java.

Indigo occurs in the plant as *indican*, a glucoside, which is extracted from the leaves of the plant, after these have been gathered at flowering time, sprinkled with water, then pressed into cement lined pits or vats and left to ferment for about two weeks. The clear water containing a solution of the coloring matter (*indigo white*) is then drawn off and oxidized to blue indigo by atmospheric oxygen, forming in the liquor as a flocculent blue precipitate (*Indigotin*). While still in a wet pasty condition, extenders, such as Chalk, Clay, etc., are sometimes added to cheapen the product. It is now necessary to wash and boil the precipitate in water to destroy the bacteria responsible for the fermentation, after which it is collected on calico, slowly dried in the air and moulded into lumps, which show the impression of the calico or leaves of the plant, used in forming it into lumps.

The principal blue coloring matter of the natural Indigo is *Indigotin*, associated with small amounts of red and brown dye-stuffs (*Indigo Red* and *Indigo Brown*), mineral matter and nitrogenous compounds. The best varieties are specifically light (floating on water), of pure deep blue color with only slight violet tinge, burn readily and show a bright metallic lustre when rubbed with the finger nail or other hard body. Being very brittle, it breaks very easily with dull blue fracture. Indigo is not soluble in water, ether, alcohol, lyes or hydrochloric acid. A characteristic reaction is the decomposition of Indigo with nitric acid to form the yellow color, *Isatin*. Indigo is soluble in chloroform, aniline, in some fatty oils and in concentrated sulphuric acid; partly soluble in benzol, toluol, phenol, acetone, amyl alcohol and in the heavier fractions of petroleum.

Indigo is a semi-transparent pigment of fair tinting strength and does not share, as a pigment, the permanency to light that it possesses as a dye-stuff. It is best employed, if at all, as a water color, in oil it loses con-

siderable brilliancy, and is unsafe in mixtures with White Lead, native Ochres, etc., fading resulting through oxidation.

In the Orient, Indigo was used in earliest times. Pliny in his *Naturalis Historia*, A.D. 77, gives lengthy description of *Indicum* stating that in addition to its use in dyeing and painting, it was also used in medicine, as an application on wounds and against fever and colds. At one time it was thought to be a metal. Old Egyptian mummies have been found on which the blue wrappings were dyed with Indigo. In the sixteenth century, Indigo was first brought from India to the Netherlands and Italy. The farmers who cultivated the woad plant in Europe were strongly opposed to its use as a dye and were successful in having its importation prohibited in England and Germany in 1577 and also in 1654. It was not until 1737 that its use became general.

The cultivation of natural Indigo threatens to become extinct owing to the large production of synthetic Indigo. During the end of the nineteenth century after twenty-five years of research work by several eminent color chemists Prof. Bayer of Munich applied for a patent (in 1880) for the making of synthetic indigo in commercial quantities. By 1900 the various processes were so far developed that the Badische Soda-Anilin Fabrik had spent about \$5,000,000.00 to manufacture synthetic indigo on a large scale and were then producing an amount equal to about one-fifth of the entire production of natural indigo.

When Indigo is dissolved by concentrated sulphuric acid, *sulphindigotic acid* is formed. This if saturated in a weak solution of soda, will yield the water soluble **Indigo Carmine**, which forms a blue paste with copper lustre.

Intense Blue is an extract of Indigo, obtained by refining the natural product through precipitation from solution; yielding a more transparent and richer color, poss-

sessing the same physical and chemical characteristics as Indigo.

ITALIAN BLUE

Venetian Blue, Turquois Blue

A beautiful fugitive cerulean blue lake color of modern introduction lacking the required durable qualities necessary as an artist's pigment. For detection see under Lake Pigments.

ITALIAN OCHRE

An especially selected variety of Raw Sienna noted for its deep rich golden color and translucency, a native product of Tocany (Sienna). It shares all the chemical and physical properties of the other Ochres, is adaptable to all techniques and has been used as a pigment since earliest times.

IVORY BLACK

Bone Black, Animal Black, Nero d' avoiro, Noir d' Ivorie, Negro de marfil, Elfenbeinschwartz

Carbon (the coloring principle) associated with *calcium carbonate and phosphate*.

Ivory Black is obtained by charring waste ivory chips, filings, etc., in closed vessels, whereby the organic matter is calcined to carbon (about 20 per cent.), giving the product its intense black color. The mineral constituents are present as calcium carbonate (lime) and phosphate (about 80 per cent.), which, although having no color value, greatly improve the soft working qualities as a pigment.

During the calcination great care is exercised that the temperature be properly regulated, as an overburnt product would suffer considerably in color brilliancy and under-calcined, would be of decided brownish color (*Bone Brown*), drying then very poorly as an oil paint.

Bone Black (*Animal Black*) is similarly obtained by

the charring of bones, of inferior color and used more extensively in the heavy paint and printing trades owing to its reduced cost, compared with true Ivory Black.

Like all bone blacks and other animal blacks, Ivory Black acts as a strong decolorizing agent in presence of most organic pigments. A solution of an organic color will be completely decolorized if filtered through bone blacks. The organic color is not decomposed in this instance, but absorbed by the bone black. Use of this property is made in the purification of sugar, removal of color from syrups and other liquids. Ivory Blacks distinguish themselves chemically from other carbon blacks in that they leave upon calcination a considerable amount (about 75 per cent.) of white bone mineral ash, which is almost entirely soluble in strong hydrochloric acid, the other carbon blacks burning almost completely, with but a trace of ash. Hydrochloric or nitric acid dissolves the phosphate of lime from Ivory Black leaving the carbon as residue.

Ivory Black is of warm brownish under-tone, intensely black in color, drying well in oil, perfectly safe and permanent in all techniques and in mixtures with all other permanent colors.

Ivory and Bone Blacks were also used by the ancients.

KERMES LAKES

Alkermes, Venetian Scarlet

This deep crimson coloring matter of yellowish-red hue is a product of the insect *Coccus Illicis*, resembling the Cochineal (see Carmine) found principally on certain species of oak trees, as also on other plants, on the shores of the Mediterranean. The plants are often completely covered with these insects, the female of which, with young, are dusty brownish colored bodies, globular in shape, as large as peas and attached to the plant in a

flocculent mass. The dried bodies in granular form are sometimes given the name **Kermes Berries**.

The Lakes prepared from Kermes are believed to be identical to those of the Cochineal, however, in general are not as brilliant as these, but of like permanency and physical properties.

Kermes is perhaps one of the oldest dye-stuffs known, it being said to have been used as a dye in the times of Moses, called by Pliny *coccigranum* and greatly valued in the days of the Roman Empire, as a dyestuff. The **Venetian Scarlet** of the Middle-ages was also obtained from Kermes. The pigments prepared from it, in ancient times, were usually precipitated on a base of chalk or gypsum, and appear consequently more opaque than the modern transparent, alumina base lakes.

In later years Cochineal has almost entirely displaced the use of Kermes; which former, in turn, is also rapidly coming into disuse, the permanent and more brilliant Alizarin Lakes being favored.

KING'S YELLOW

(See Chrome Yellow and Orpiment)

An especially brilliant pale variety of Chrome Yellow (Lead Chromate, $PbCrO_4$) sometimes also produced by admixture of Zinc White with Chrome Yellow, in both instances it shares the chemical and physical properties of the Chrome Yellows.

As a water color more permanent mixtures of Cadmium Yellow and Zinc White are usually sold as Kings Yellow.

The yellow sulphide of arsenic known and used by the ancients as **Orpiment** is also called King's Yellow by some authors. This latter pigment has been in disuse, however, for many years.

LAKE PIGMENTS

A true theoretical lake pigment is best represented by a compound of which the natural or artificial organic coloring principle is united in equivalent proportions with a metallic inert base to form an insoluble, transparent unalterable pigment.

Practically however, this is not followed as there are several conditions entering into the actual formation of a lake pigment.

For a more clear understanding we might comparatively regard a lake as a insoluble neutral salt, such as is formed by precipitation from solutions in inorganic chemistry, when certain mineral acids and bases unite in molecular proportions. Such compounds, or lakes, of high color concentration are sometimes called *toners*, because of their powerful tinting strength, they are used in toning mixtures of colors to standards, in heavy-paint manufacture.

In chemistry a base is defined as the hydroxide of a metal or metallic radicle having a characteristic alkaline or caustic reaction in water-solution, effecting neutralization of acids. The color maker interprets and applies the meaning of base in a much broader sense. In the production of lakes, especially applicable to those with artificial coloring matters as color principle any inert, colorless or white, usually transparent body on which the coloring matters are precipitated is termed a *base*, sometimes also called an *extender or carrier*.

The lake pigments are divided into two groups, those produced with

I. Natural coloring matters

- a. Animal origin (Lac, Cochineal etc.).
- b. Plant or vegetable origin (Quercitron Bark, Madder Root etc.).

**II. Artificial coloring matters = Coal-tar derivatives
(Alizarin, Aniline dyes, etc.).**

I. The Natural Coloring Matter

To the first class belong the natural color extracts such as lac, cochineal, fustic, logwood, madder root, Quercitron bark, etc., which have formed the coloring principles in dying and lake making since earliest times. The artificial coloring matters date only from the middle of the nineteenth century and already threaten to entirely displace the natural dye-stuffs, both as dyes and for lake-color making, yielding colors far more brilliant, permanent and dependable than the natural products.

The natural organic coloring matters, which are mostly of an acid character, combine with metallic bases, such as alumina, tin, iron, lead, etc., to form colored insoluble precipitates. In practice there is usually an excess of base, the coloring matter only being partly in chemical combination and often also partly carried down in a kind of mechanical mixture with the base. The excess of base is usually intentional to produce a cheaper product in which the coloring matter is then present in desired percentage. The genuine cochineal Carmine is representative of the nearest perfect lake, in that, here the coloring matter is combined with the smallest amount of base possible to yield a non-bleeding, insoluble (in oil and water), highly concentrated lake, lacking only permanency to give it all requirements of an ideal lake.

The metallic base usually employed is alumina, it yielding the most brilliant, concentrated and transparent lakes.

The usual procedure, in making a lake pigment, is to prepare a clear decoction of the coloring matter, as highly concentrated as possible, to which is then added solutions of the base. The color of the resultant lake is greatly influenced by the conditions under which precipitation

takes place, depending mostly upon the degree of concentration, acidity or alkalinity and temperature of the solutions during precipitation, as well as the various bases employed.

Certain natural coloring matters (called *substantive*) exist ready formed in nature and do not require any special base or mordant; producing nearly the same color directly on various bases, an example of which is cochineal; others (called *adjective*) do not develop their color until combined with certain bases, yielding different colored lakes according to the base or precipitating agent employed, madder root being representative of this class, yielding with alumina, red lakes; with iron, deep dull violet lakes, etc.

Only with certain few exceptions (such as the madder root extracts, etc.) practically all of the lakes produced with the natural coloring matters, are not permanent to light.

II. Artificial Coloring Matters

To this class belong the majority of lake pigments in common use, the production of which, since the middle of the nineteenth century, has increased so rapidly as to almost entirely displace the lakes made from the natural color extracts. The development of the dye industry has made it possible to procure lake pigments of almost any conceivable color, the greater number of which, unfortunately lack even moderate permanency and are therefore impractical as pigments. Certain dyes, when applied to fabrics, will yield colors of considerable permanency (this being chiefly due to chemical action between the organic constituents of both dye and fabric) but when used for lake making, the same dye will oftentimes produce a very fugitive color.

The lake pigments made from artificial coloring matters are also not true lakes as the color is not solely com-

bined with the precipitating agent, but always contains the addition of another substance in connection with the lake proper, which substance varies according to the purpose for which the respective lake is intended. This substance is known as the base, carrier or extender, and according to its composition can greatly influence the transparency, gravity, tinting power and hue of the prepared lake. To obtain the better quality, transparent and brilliant lakes, Alumina is employed as the perfect base. Other bases, such as Whiting (precipitated chalk), Blane fixe, China Clay, Gypsum, Zinc White, etc., when used in varying amounts, give the resultant lakes different characteristic qualities. Sometimes colored bases, such as Red Lead, Oehres, Umbers, etc., are employed to yield very brilliant pigments.

The three things necessary for making a lake pigment from artificial coloring matters, are:

I. The Coloring Matter $\left\{ \begin{array}{l} \text{Substantive or Basic dyes} \\ \text{Direct Dyes Acid dyes} \\ \text{Adjective or} \\ \text{Mordant Dyes} \end{array} \right.$

II. The Precipitating Agent

III. The Base (Carrier or Extender)

The coloring matters are perhaps of most importance, as in connection with the proper precipitating agent, together with any of the bases already mentioned, innumerable different colored lake pigments may be obtained.

The *Substantive* or *Direct Dyes*, fix themselves chemically, or by absorption, directly on a suitable base. Of this class the *Basic Dyes* are salts of certain complex organic bases, which form colored precipitates with certain weak organic acids. The *Acid Dyes* are not all of acid nature, but are termed acid owing to their property of dyeing wool and silk fabrics in baths containing a small

quantity of free acid. They are precipitated from solution by acids and metallic salts. The coloring matters termed *Adjective* or *Mordant dyes* are usually not themselves, of the desired color, but require the aid of a substance, called the *mordant*, to develop the color and fix it. Many mordants react chemically with the dye. Thus different colors can be obtained from the same dye by using different mordants. The lakes prepared from this class are characterized by their permanence.

The lake pigments prepared from the natural coloring matters were known and used for many centuries. They are described by Pliny in his "Naturalis historia" and mention is made of them by other early writers. The name "lake" is derived from the dye-stuff used and known as "lac" by the early Italian dyers and was perhaps the same substance, as is used today, under this name (see Lac Lake). In order to fix and develop this dye on the fabric a mordant composed of the salts of aluminum and tin were used and it was found that some of the dye combined with the mordant to form an insoluble compound of color and base, which was collected from the liquor in the form of serum and after drying was sold as "laccia" to artists. Later, other lake colors were obtained and were soon produced independent of the dyers vat, when today we find the manufacture of lake colors ranking as one of the principal color-industries.

Starch is sometimes added to lake pigments as an adulterant, the detection of which may be made by warming a sample of the pigment in water to the boiling point. If starch is present the liquid will thicken to a gelatinous paste.

Hydrochloric acid decomposes nearly all lake colors, leaving insoluble residues of the base (barytes, clay, etc.). By adding an excess of ammonium hydroxide to the acidified solution, alumina (*Alumin'um hydroxide*) or

tin hydroxide will be formed as a white precipitate. The alumina or tin hydroxide having been used as a base for the lake.

The permanent lake colors, owing to their brilliancy and transparency, are most valuable as over-glazing colors and mixtures with certain metallic pigments, such as White Lead, Chrome Yellows, Verdigris, etc., and most raw earths are best avoided as being of questionable durability.

Most lake pigments bleed their color somewhat in alcohol and a few, even in water.

LAMP BLACK

Noir de bougie, Nero fumo, Negro de humo,
Lampenschwarz, Vegetable Black

A flocculent black form of commercially pure *carbon-C.*

Lamp Black is a fine flocculent kind of soot, the finer varieties obtained principally, as the name implies, from wick lamps, in which oils rich in carbon, are burnt with insufficient air for complete combustion. The soot, which is deposited on plates held in the flame, is collected and ready for commercial use. The better varieties are obtained from fluid fatty oils, however very good products are also made from fats, grease, tallow, coal-tar oils, resins, naphthalene, etc.

Lamp Black is of strong black color, very light in gravity, with considerable opacity and ranks high with the most permanent and stable pigments, being perfectly safe in mixture with all pigments, unaffected by impure air, gases, acids or alkalies and insoluble in all usual solvents. (See Blue Black, Carbon Black, Ivory Black.)

Lamp Black is adaptable to all techniques, yielding in mixtures with Zinc White, grays with marked bluish-tint. The hard film of dry Zinc Whites, in oil; is made much

more flexible when Lamp Black is present together with the Zinc White in grays. Lamp Black is a very slow drier in oil.

Great quantities of Lamp Black are made annually, being chiefly consumed in the making of printers ink, heavy-paints, etc. Lamp Black forms the coloring principle of the Chinese Indian Stick Ink.

Its use as a black pigment dates back to great antiquity.

LEMON YELLOW

Strontian Yellow, Strontium Chromate, Jaune de strontiane, Giallo di stronziana, Amarillo de estronciana, Baryta Yellow, Barium Chromate, Yellow Ultramarine, Permanent Yellow, Juane de baryte, Gialla di barite, Amarillo de barita, Oltremare giallo, Outremer jaune, Amarillo ultramas, Citronengelb

Generally *Strontium Chromate*— SrCrO_4 ; or *Barium Chromate*— BaCrO_4 .

Strontium Chromate is of decided lemon hue, more pale in color than Zine Chromate and stronger than Barium Chromate. Both Strontium and Barium Chromates are obtained as precipitates when a solution of a Strontium or Barium salt, such as Strontium or Barium Chloride, is mixed with a solution of a chromate salt, such as Potassium Bichromate.

Strontian Yellow is a very permanent pigment, can be safely mixed with other durable colors with exception of certain native ochres, which only in some instances tend to slightly alter the hue, due to the presence of hydrated oxide of iron.

Strontian Yellow is a good drier in oil and has considerable transparency both as an oil and water color. Acetic Acid and Ammonium Salts dissolve this pigment. It is also only very slightly soluble in water. Used prin-

cipally as an oil and water color pigment and not good in Stereochromy and Fresco.

Owing to the cost of this pigment there is great temptation to adulterate with Chrome Yellows, detection of which is made easily evident by the resultant formation of black lead sulphide, when the pigment is exposed to hydrogen sulphide gas or to a solution of sodium sulphide. Pure Strontian Yellow is not blackened by these.

Barium Chromate is also a very permanent pigment of paler lemon hue than Strontian Yellow and is unquestionably the most reliable of the yellow chromate colors. It is obtained in similar manner as the Strontian Yellow, namely by precipitation and possesses almost identical chemical and physical characteristics. In water it differs, however, from the Strontium Chromate in that it is practically insoluble. It is not blackened by sulphur gases or sodium sulphide. The hue sometimes takes on a greenish tinge under exposure to strong sunlight.

Barium Chromate is soluble in Hydrochloric Acid or Nitric Acid. Barium Chromate when dissolved in hydrochloric acid, will yield a yellow colored solution, and if alcohol is added and warmed, the solution will turn green in color with characteristic odor (aldehyde, see page 186). To this acid solution, add sulphuric acid to obtain an insoluble white precipitate of Barium Sulphate.

Barium Chromate imparts a green color to the lower part of the Bunsen flame.

Permanent Yellow is usually understood to be a mixture of Barium Chromate and Zinc White or Strontian Yellow and Zinc White, or Zinc Yellow and Zinc White. As such they are all of rather weak color strength, opaque and drying slowly in oil, but dependable in use with other safe pigments and permanent to light and are not blackened by hydrogen sulphide gas.

LITHARGE

Massicot, Lead Oxide. Burnt White Lead

Lead Monoxide (Plumbic oxide)—PbO.

By roasting White Lead at a temperature sufficiently high to melt the oxide thus formed, a yellowish-red crystalline mass called **Litharge** is obtained after the mass cools and solidifies. The soft yellow powder obtained by heating White Lead, at a high temperature, is another modification of Litharge known as **Massicot**, which is permanent to light as a pigment in oil. Like all pigments containing lead, owing to their sensitiveness to impure air containing sulphur compounds in gaseous form, great precaution is necessary in their use, the black sulphide forming only too readily. (See **Minium** and **White Leads**.)

Litharge has another chemical property of which important use is made in the preparation of siccatif and varnishes. When in mixture with oils, especially applicable to linseed oil, a chemical combination of the lead oxide and the oil takes place forming an insoluble (in water and many solvents) lead soap, lead linoleate, which dissolves in the rest of the oil to give a kind of varnish, which dries very rapidly to a hard elastic film. Care must be taken not to have too great a quantity of lead oxide in admixture with the oil, it being a very powerful drier and very liable to cause cracking and darkening of the oil and paint.

Lead Oxide is soluble in acetic and nitric acids. When on boiling lead oxide with hydrochloric acid, if sulphuric acid is added, insoluble white lead sulphate is formed.

LITHOPONE

Silver White, Albalith, Beckton White, Orr's White

Essentially a compound of *Zinc Sulphide* and *Barium Sulphate*— $\text{ZnS} + \text{BaSO}_4$.

Lithopone has been improved in recent years so that a product of great uniformity is produced, lacking many of the objectional properties peculiar to most of the early Lithopones, the parent of which can be said to be Orr's White, patented in 1874 by John B. Orr of England.

The method of producing Lithopone is theoretically very simple, it requiring though considerable technical and practical skill to obtain uniform and dependable results. Solutions of Barium Sulphide and Zinc Sulphate are poured together, the proper concentration and temperature being carefully regulated, to yield a double precipitate of Zinc Sulphide and Barium Sulphates which is then dried and heated in furnaces to glowing, from which it is thrown into water; washed, ground in mills and dried. The early Lithopones usually contained upward to 10 per cent. of Zinc Oxide, directly due to overheating, this sometimes also producing a slight discoloration.

The better varieties of Lithopone have great covering and hiding power, are very opaque and find wider application as a heavy or house-paint pigment, than as an artists' color.

Lithopone is perhaps the most intensely white pigment in use, having strong tinting properties and exceptional covering qualities; of excellent, smooth and fine, uniform texture with remarkable inertness in most vehicles, applicable to all painting techniques, excepting those of strong acid nature.

Acids decompose the Zinc Sulphide with formation of Hydrogen Sulphide, leaving barium sulphate unaffected as an insoluble white residue. Lithopone is not affected by sulphurous gases or compounds. In oil, Lithopone is not a quick drier, comparing more to Zinc White in this respect. Lithopone is also non-toxic.

Some poor varieties of Lithopone exhibit a peculiar

property of turning gray, when exposed to the action of moisture and direct sunlight the white color however usually returning when removed from these influences. It is generally accepted, that this decomposition is the result of a reduction of the Zinc Sulphide content to metallic Zinc and Hydrogen Sulphide, this reaction being developed by the actinic rays of sunlight. Owing to this peculiarity, mixtures with pigments containing either lead or copper are best avoided, the black sulphides of these metals being likely to form.

Mechanical mixtures of natural or artificial Barium Sulphate and Zinc Sulphide, in the same proportions as contained in Lithopone, yield a product differing absolutely in physical character. In precipitating the Barium Sulphate and Zinc Sulphide simultaneously and then treating this precipitate as already described, the molecules of each substance become so intimately combined as to almost give the appearance of a chemical, rather than a physical combination; whereas in a mechanical mixture the identity of each of the two substances is not lost, each being individually recognized microscopically, by their characteristic structure.

MADDER LAKES

Madder Lake, Madder Lake Extra Deep, Lacca di garance, Laque de garance, Laca de garanza, Krapplock, Rose Madder, Garance Rose, Garance rosa, Garanza rosa, Rose Madder Deep, Pink Madder, Madder Carmine, Rubens Madder, Rose Dorée, Madder Purple, Madder Brown, Crap Lakes

Essentially lakes, on Alumina base, coloring principles of which are *Alizarin*— $C_{14}H_8O_4$ —and *Purpurin*— $C_{14}H_8O_5$.

A great number of organic lake pigments very per-

manent to light are listed under this group. The best are essentially combinations of alumina hydrate and Alizarin, which is the most important coloring principal obtained from the Madder root (*Rubia tinctorium*). The soft cellular tissue of the Madder root is much richer in coloring substances than any other part of the plant. The coloring matter exists in the plant in the form of glucosides, principal of which is Alizarin and Purpurin.

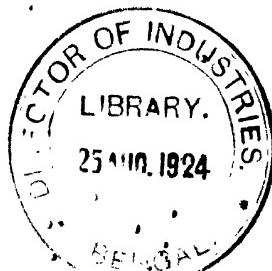
Alizarin yields the more permanent and brilliant lakes of deep rich crimson to violet and maroon hue, varying according to the concentration, purity and the kind of base on which the color is precipitated.

Purpurin yields more orange and red hue lakes, usually slightly less permanent than the Alizarin Lakes.

Many different color lakes are obtained from the Madder root extracts, depending principally upon certain conditions under which the formation and precipitation of the lake took place, namely, the hue being considerably altered when various bases are used; likewise the temperature, concentration of the solutions and purity affecting the resultant color.

The genuine Madder Lakes from the Madder root have complex color constituents comprising mixtures of Alizarin and Purpurin, etc., and yield in consequence a considerable number of varying colors, all of which are among the more permanent lake pigments adaptable to the different techniques, not good however, for fresco or stereochromy. The most permanent is the deep Alizarin Madder Lake. In consequence of their brilliancy, transparency and permanency, the Madder Lakes, as also the coal-tar Alizarin Madder Lakes, rank as the most useful over-glazing colors.

Since synthetic, or coal-tar Alizarin, has been developed from anthracene, the natural Madder extracts have been practically displaced both as dyes and as coloring principals for lake pigments.



The synthetic Alizarins, and similar derivatives are usually of richer hue and when properly manufactured, are more permanent than the natural color extracts of the madder root, which almost always contain at least traces of less permanent color constituents.

Natural Madder Lakes do not bleed in water or alcohol, are unsafe in mixture with certain native raw earths, white lead, and some other metallic colors, such as Chrome Yellows, etc., with Permalba, admixtures are safe and form permanent pale tints of the Madder Lakes.

Extracts from the Madder root were used for dyeing since earliest times.

Turkey Red is obtained from the madder root.

Sodium hydroxide entirely dissolves Alizarin and Madder Lakes (an alumina base) to a blue violet solution (Purpurin yields a cherry red solution), which upon the addition of dilute sulphuric acid in excess, loses its color with formation of a flocculent colored precipitate of the dye-stuff (orange-yellow in color if Alizarin and bright red if Purpurin) leaving the supernatant liquid practically colorless. Carmine or Carmine Lakes are detected by their leaving the acidified solution more or less intensively red in color.

Alizarin and Madder Lakes are insoluble in water or alcohol, a colored solution would indicate the addition of soluble dye.

MAGENTA

Aniline Violet Lake, Violetto d' anilina rossiccio
Violet d' aniline rougeâtre Magenta, Violets de
anilina rojiza Magenta

A brilliant lake pigment of characteristic magenta hue, the coloring principal of which is an aniline derivative precipitated on a base of Alumina, or any other suitable extender. Magenta is not practical as a pigment for artists' use, it being one of the most fugitive aniline colors,

requiring exposure to direct sunlight for but a short time to effect marked fading. It is very unsafe in admixture with most metallic colors.

Magenta has only been developed since the middle of the nineteenth century and should under no consideration appear on the artist's palette, when even moderate permanency is a requirement.

MALACHITE GREEN

Green Verditer, Green Copper Carbonate, Mountain Green, Green Bice, Vert de Montagne, Mineral Green, Verde minerale, Vert minéral, Verde mineral, Berggruen, Malachitgruen

Basic Copper Carbonate - Cu₂O₃.Cu(OH)₂.

Malachite Green is found native in America, Europe, Asia and Africa. The raw mineral, after careful selection, free from earthy substances, is ground as finely as possible and is then suitable as a color pigment.

In chemical composition it is closely allied with the blue basic copper carbonate (see Air Blue) containing only less of the carbonate.

Like all copper compound pigments, it is sensitive to impure air, very readily becoming blackened in contact with sulphureus gases or sulphur compounds and often fading slightly under exposure to strong light. Admixtures with colors containing sulphur or sulphur compounds are, therefore, best avoided, principal of which are Cadmium Yellows, Aurora Yellow, Ultramarines, genuine Vermilions, etc. As an oil color, Malachite Green is more permanent than in any other technique, especially is this true when protected by a strong varnish film.

Malachite Green is, also, made artificially. The product is usually far less brilliant, but possesses the chemical and physical properties of the native mineral.

Malachite Green is soluble in acids, with effervescence to a clear solution, which will turn to a deep blue color upon addition of ammonia water in excess. Heat destroys this pigment, yielding the black copper oxide.

Malachite Green is unquestionably the oldest known green pigment, in use over three thousand years, confirming evidences of which have been found in Pompeii and Rome and in ancient Egyptian ruins.

MANGANESE VIOLET

Mineral Violet, Permanent Violet, Nuernberger
Violet

A double salt of *Phosphoric Acid* with *Manganese* and *Ammonium*.

This permanent violet hue pigment is only seldom in demand by the artist. It is of truer violet hue than the more reddish Cobalt Violet and together with this and Violet Ultramarine they form the three principal permanent violet pigments.

Manganese Dioxide and Ammonium Phosphate are melted together, with evolution of Ammonia, to yield a fused mass of violet color, which is then digested with phosphoric acid and heated until a rich violet hue is produced. After cooling it is then thoroughly washed with water and phosphoric acid, until the residue pigment, which remains, is no longer soluble in water. Manganese Violet is soluble in hydrochloric acid, with evolution of chlorine. It is decomposed by lyes and caustic lime, to manganese oxide, with evolution of ammonia gas.

Manganese Violet is permanent to light, safe in admixture with other colors and adaptable to all techniques, with exception of fresco and stereochromy, in which it is not compatible with the alkalies present in these techniques.

A test for this pigment is made by melting a sample

of the color in question with soda on a porcelain dish, or on a platinum wire, when a bright green molten mass of sodium manganate (Na_2MnO_4) will be produced, which is soluble in water to a green solution and which after standing for some time changes to a violet color (Sodium Permanganate, NaMnO_4).

MARS COLORS

Mars Orange, Mars Yellow, Mars Red, Mars Violet, Mars Brown

The Mars Colors are artificial ochres, deriving their color from the *hydrate* and *oxide of iron*.

Mars Yellow is obtained by precipitating a salt of iron with alumina by means of either caustic lime, soda or potash. The greater the amount of alumina employed, the paler the product obtained.

Mars Yellow when subjected to calcination, yields, depending on the duration and degree of heat under which this is carried on, colors of different hue, namely **Mars Orange, Mars Red, Mars Brown, Mars Violet, etc.**

It is very important that the Mars Colors be thoroughly washed free from any soluble salts, after which they can be accepted as perfectly permanent (to light) color pigments.

In mixtures with certain organic pigments Mars Yellow and Orange sometimes exercise an injurious effect, likely due to a combination of the iron hydrate with the organic coloring matter. This tendency is more marked in the lighter colors, those of deeper hue, produced by higher calcination, showing greater stability.

Mars Colors are of recent introduction and possess no greater permanency or brilliancy of color than the best varieties of native ochres or natural iron-reds (see Ochres) with which they are identical in chemical and physical properties.

MAUVE

Mauve, Mauve II (bluish), Aniline Violet Lake, reddish and bluish; Violetto d' anil, bluastro Malva; Violet d' aniline bleuatre, Mauve; Violeta de aniline, Malva

In 1856 the English chemist Wm. Perkins discovered the color **Mauve** accidentally, while experimenting with Aniline, a colorless oil derived from Coal Tar. **Perkins Violet** was sold as **Mauvein**, or **Mauve**, named after the flowers of the mallow. This color marked the beginning of the coal-tar color industry, which in recent years has developed, synthetically, an inconceivable number of dyes of every imaginable hue, most of which unfortunately are much too fugitive for practical application as coloring principles for pigments. (See Coal Tar Colors.)

Mauve is of most brilliant violet hue, but very unsafe for use, rapidly fading when exposed to direct sunlight.

Used in any technique and in mixture with many metallic colors, Mauve will eventually fade and for this reason should not be used by the artist.

Mauve II is of more bluish hue.

MINERAL GRAY

A translucent, permanent pigment of very little tinting strength, drying well as an oil color. The better product is obtained from inferior varieties of *lapis lazuli* (genuine Ultramarine). **Gangue** (vein-stone) tinted with Ultramarine is often offered as Mineral Gray. This color is in but little demand, the same shade being produced by mixture of Lamp Black, Ultramarine and Zinc White.

MINERAL YELLOW

Cassel Yellow, Turners' Yellow, Veronese Yellow

Oxychloride or Basic Lead Chloride— $PbCl_2 \cdot 7PbO$.

Mineral Yellow has come into total disuse since the

development of the much brighter Chrome Yellow. Mineral Yellow is also well known under the name **Turners' Yellow**, named after its inventor Jas. Turner in 1870.

Mineral Yellow can be prepared by melting litharge together with ~~sal ammoniac~~ (ammonium chloride).

When treated with warm dilute nitric acid, Mineral Yellow, is entirely dissolved to a colorless solution, which, upon the addition of silver nitrate, will yield a white precipitate of silver chloride.

Mineral Yellow is also soluble in caustic soda. When heated with carbon, it is gradually converted into metallic lead.

Mineral Yellow varies in hue from a reasonably bright yellow to a dark orange yellow of considerable opacity as an oil or water color. Like all pigments containing lead, sulphurous gases or compounds cause a decided discoloration. Mineral Yellow is not to be considered permanent under exposure to light and air.

NAPLES YELLOW

Jaune de Naples, Jaune d' Antimoine, Jaune de Naples, Giallo di Napoli, Amarillo de Napoles,
Neapelgelb

Naples Yellows consist essentially of *Lead Antimoniate* — PbSb_2O_6 .

This pigment was originally thought to be a natural earth, of volcanic origin, reference to it being made in very ancient times. Very early evidence of its use is found, as an enamel and on decorated pottery. There is record of it being secretly manufactured in Naples about 1760.

By prolonged roasting of finely mixed oxides of lead and antimony, Naples Yellows are obtained. The hues vary according to the degree of heat and its duration. The lighter colors are produced at high temperatures. The addition of tin oxide to the mixture, before roasting, will yield Naples Yellows of rich light yellow hue.

Naples Yellow is perfectly permanent to light and pure air, very opaque, of little tinting strength, drying well in oil. Its sensitiveness toward sulphur gases and compounds renders it practical only in oil, in which technique it is protected by an oil or varnish film. Contact with metallic iron, tin and zinc causes this pigment to become gray. It is, therefore, advisable to use horn or wooden spatulas in preparing or mixing Naples Yellow.

Hydrochloric acid and nitric acid slowly dissolve Naples Yellow; the resultant solution is colorless. Alkalies also decompose this pigment.

Naples Yellows are today mostly imitated by mixture of Cadmium Yellows, Permalba, Zinc White, and Light Red or Venetian Red to yield colors of excellent permanency and are to be recommended, especially in mixtures, for their durability, in preference to the genuine Naples Yellow.

NEUTRAL TINT

Teinte neutre, Tinta neutra, Neutraltinte

Mixtures of Indigo, Black and Alizarin Crimson, used as an oil and water color, of considerable permanence; sharing, however, the lack of absolute permanency of its Indigo constituent.

NEW BLUE

Outremer clair, Oltremare chiaro, Ultramar claro

(See Ultramarines.)

OCHRES, NATURAL AND CALCINED

Under the classification of Ochres we find listed a variety of natural earths, the coloring principle of which is iron oxide (*ferric oxide*— Fe_2O_3) and various iron hydroxides.

NATURAL YELLOW AND BROWN OCHRES

The yellow and brown ochres derive their color from the presence of iron hydroxides. There are several iron

hydroxides, which exist as mineral species. The Yellow and Brown Ochres derive their color, principally from three of these, Yellow Haematite, *Xanthosiderite*— $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$; Brown Haematite, *Limonite*— $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ and Bog-iron ore, *lyonite*— $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$. These ochres are chiefly composed of either or several of these hydroxides in varying amounts, together with more or less clay, also sand, chalk, gypsum, barytes and occasionally silica, diatomaceous in nature. This varying composition greatly influences the color, tinting strength, opacity and purity of the ochre. The ochres selected for artists' pigments are chiefly from France, Italy, Germany and Spain, altho in almost every country ochres are to be found. The ochres with the larger percentages of iron hydroxides are more transparent and of stronger color than those, which contain large amounts of clay or other earthly substances making them opaque, dull and of weak color.

Artificial ochres are prepared by precipitation of iron salts and zinc or aluminum salts, with solutions of soda or limewater. The colors obtained by this method are called **Mars Colors** (**Mars Yellow**, **Mars Brown**, etc.) They are composed principally of iron hydroxide, together with more or less alumina, zinc carbonate or chalk, and are for this reason usually more transparent than the natural ochres.

It is necessary to thoroughly wash and leivate natural ochres before their use as artists' pigments thereby washing the color free of sand and any soluble salts, which would otherwise be of considerable detriment, greatly affecting their durability as pigments.

When pure all ochres rank high with the most durable and permanent pigments. They have been in use since very ancient times, in all painting techniques.

Hydrochloric acid dissolves the iron from ochres yielding a yellow solution (iron chloride); the remaining

undissolved sediment is composed chiefly of clay and other earthly substances. Ochres to which dyes or lakes have been added to brighten the color, usually bleed these admixtures in alcohol (to which a little ammonium hydroxide is added). The addition of Chrome Yellow is readily detected (see Chrome Yellows). Ochres when heated in a test tube should not yield a tarry condensation on the cool side of the tube. Ochres should be insoluble in boiling water. Basic iron sulphates are detected as stated under Indian Red, page 66.

Mixtures of the natural ochres with organic pigments and lake colors are best regarded as of uncertain stability, the iron hydroxides having a tendency to reduce these colors.

Ochres are sometimes tinted with Chrome Yellow (Chrome Ochres) or fugitive yellow lake colors to enhance their hue. This should, at best, be regarded as an undesirable addition, very readily affecting the permanency of the pigment.

The Yellow and Brown Ochres appear under the following names, **Yellow Ochre**, Ocre jaune, Oeria gialla, Ocre amarillo, Licher Ocker; Trans. Golden Oehre; Ocre d'or, trans.; Oeria dorata; Ocre de oro; Goldocker; Golden Oehre; Roman Ochre; Oere de Rome; Oeria di Roma; Oere de Roma; Ocker roemisch, Brown Oehre, Oxford Oehre.

Raw Sienna, Terre de Sienne, Terra di Siena, Tierra de Siena is a variety of yellow ochre, which is found principally in Toscany, Italy. It is of deep rich color and differs from the ordinary ochres in that it possesses exceptional transparency.

NATURAL RED OCHRES

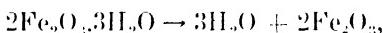
The natural red ochres are of similar composition containing a greater percentage of iron oxide, to which is due their characteristic red color.

Like the natural yellow ochres, the natural red ochres, if properly prepared by thorough washing and levigation, belong to the most durable and permanent pigments for all painting techniques.

To these colors belong the genuine Indian Red, Venetian Red, Terra Pozzuoli, Terra Rosa, Red Chalk, Bole, Ruddle, Red Iron Ore, Red Hæmatite, Bolus and the Sinopis and Rubica of ancient times.

CALCINED OR BURNT OCHRES

When natural ochres are roasted, the iron hydroxides lose their water content, being thereby converted into iron oxide,



thereby causing a change of color from yellow to red.

The different varieties of yellow ochres yield upon calcination products varying in color from orange-red to deep red-brown, the resultant hue being also partly affected by the temperature during roasting. They share the permanent and durable properties of the raw ochres in all techniques.

The following colors belong to the burnt ochres; Light Red, Brun rouge, Bruno rosso, Pardo rojo, Burnt Ochre, Ocra bruciate, Ocre brûlée, Ocre tostado, Gebrannter Ocker, Bt. Roman Ochre.

OLIVE GREEN

Verde olive, Verde oliva, Olivengruen,
Olive Lake, Aliz. Olive Lake

Olive Greens are obtained by mixtures of several colors. Manufacturers use different pigments to obtain this color, the selection of which is governed usually by the purpose for which the color is intended. If the pigment should resemble a lake color, then such colors as the yellow lakes, the more transparent browns and blues are employed in proper mixture. On the other hand

should opacity be more essential, such yellows as the Chromes or Cadmiums, with Prussian Blue, Indigo or Ultramarine and Raw Sienna will yield Olive Greens of good body and color.

This color is best prepared by the artist when needed, thereby controlling the exact composition of the mixture, to meet his requirements.

ORPIMENT

Kings Yellow, Arsenic Yellow, Jaune Royal,
Koenigsgelb

Yellow sulphide of arsenic, *Arsenous Sulphide*— As_2S_3 .

At one time this pigment was used quite extensively, but has now come into disuse. It is described by Pliny in his "Naturalis historia," A.D. 77, and was also known to the early Egyptians.

Kings Yellow is found native as the mineral orpiment, in various countries, or can be made artificially by precipitation, or sublimation.

Altho of very brilliant, rich, yellow hue and possessing considerable body, Orpiment fades readily on exposure to light and reacts in mixtures with pigments containing lead or copper, to form the respective black sulphides. Also, with such colors as Ultramarines, Cadmium Yellows, and the Iron Oxides it is unstable. Orpiment owing to its arsenic content is very poisonous.

Strong hydrochloric acid, caustic soda or alkaline carbonates dissolve Orpiment to a colorless solution.

OXIDE OF CHROMIUM, OPAQUE

Chromic oxide, Oxyde vert de chrome, Ossido di cromo verde, Oxido de cromo verde, Gruenes Chromoxyd

The green oxide of Chromium, *Chromic Oxide*— Cr_2O_3 . This pigment was first introduced by Vauquelin in 1797.

It is of dull green color varying in hue, depth and opacity according to the process, wet or dry, and conditions under which it is produced. It is generally of good opacity, very stable and inert in mixtures and exceptionally permanent in all painting techniques, and employed as a vitrifiable pigment in the enameling of pottery.

Acids, alkalies, sodium sulphide or hydrogen sulphide no not affect this pigment.

Mixtures of Chrome Yellows and Prussian Blue, or Ultramarine, are unfortunately commonly to be found, offered as Chrome Greens. These mixtures bear no comparison with the true oxide of chromium greens in physical and chemical properties.

OXIDE OF CHROMIUM, TRANSPARENT

Emeraude Green, Viridian, Vert emeraude, Verde smeraldo, Verde esmeralda, Feuriges Chromoxyd, Guignet Green, Emerald Oxide of Chromium, Pannetiers Green, Mittlers Green

Hydrated chromic oxide— $\text{Cr}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$.

About 1834, Pannetier produced by secret process a very brilliant Chrome Green, which several years later was manufactured by the patented process of M. Guignet, whose method is still in use and by whose name this pigment is also known.

This pigment is produced by thoroughly mixing and calcining 8 parts of boracic acid with 3 parts potassium bichromate, treating the resultant fused mass of green color, with cold water, washing by decantation, grinding while wet, thoroughly washing with hot water to free from any soluble salts (potassium borate) and then carefully drying.

Oxide of Chromium, Transparent, is one of the most desirable and valuable pigments for the artists palette, of excellent tinting strength, color depth, beautifully

transparent, durable and unalterable in all painting techniques and in mixtures with other pigments, also unaffected by sulphurous gases, dilute acids or alkalies and perfectly permanent to light.

Transparent Oxide of Chromium should not be confused with transparent Chrome Greens, produced by admixture of Prussian Blue with certain transparent yellows, as these latter do not share in any degree the permanency of the former.

BLUE GREEN OXIDE AND GREEN BLUE OXIDE

In recent years very permanent and brilliant blue green pigments are produced by strong calcination of Chromic Oxide— Cr_2O_3 , Aluminum oxide— Al_2O_3 and Cobaltous Oxide CoO .

The greater amount of Chromic Oxide present will produce a more greenish-blue hue. If greater quantity of Aluminium oxide and Cobalt are added to the mixture, the yield will be of more bluish color.

These pigments are also absolutely permanent to light, unalterable and durable in all painting techniques, unaffected by alkalies or acids and have no action on other pigments in mixtures.

PAYNE'S GRAY

Gris de Payne, Grigio di Payne, Gris de Payne

A color prepared principally from Black, Alizarin Madder and Indigo, used only in oil and water color painting.

Payne's Gray, like Neutral Tint, is prepared by various color manufacturers from different constituents and where permanent and durable pigments are employed for this mixture, a color of good stability is obtained. Mixtures of Ultramarine, Ochre and Ivory Black or Davy's Grey (Slate Grey) yield a very dependable Payne's Gray. It is best prepared by the artist, who can then select his pigment to meet his requirements.

PEACH BLACK

A variety of Carbon Black of strong color, comparing in physical and chemical properties to Lamp Black. Like Lamp Black, it is permanent in all painting techniques and can be safely used in a mixture with other dependable pigments.

PERMALBA

A true composite pigment consisting essentially of a compound of Barium Sulphate.

Permalba is an **Artist's Permanent White** introduced by F. Weber Company of Philadelphia, after having undergone exhaustive laboratory and practical tests, regarding the unusual chemical and physical properties common to this pigment.

Permalba is absolutely permanent to light, remaining unaffected upon exposure to impure air, dampness and gases; is the most opaque white pigment with greatest tinting strength; will not discolor with age; is chemically stable and inert towards any other pigments in mixtures; is not acted upon, or does not react with any vehicles or mediums employed in any painting technique; does not contain any lead or zinc; is non-toxic; is acid and alkali resistant and is not discolored by sulphur gases or sulphur compounds; yields tints of exceptional brilliancy and true color value when mixed with any color; withstands high baking temperature without discoloration; photographs white and is not acted upon, or altered by the actinic light rays.

Permalba when ground in the purest oil, yields upon oxidation (drying) of the oil, an elastic film, with no tendency to crack or become horny or brittle.

Permalba is sold as an artist's oil, water, tempera and pastel color and is rapidly displacing other less durable white pigments on the artist's palette, where permanency and durability are of first consideration.

PERMANENT GREEN

Vert perm., Verde perm.

Permanent Greens are mixed colors prepared by various manufacturers from a selection of permanent pigments to obtain greens of different hues. Usually the most durable yellow and blue pigments are employed in varying amounts to produce a light, medium and deep Permanent Green. The Oxides of Chromium, Transparent or Opaque, are best used in conjunction with permanent yellows or blues.

PERMANENT VIOLET

(See Manganese Violet)

PERMANENT WHITE

Blanc Fixe, Baryta White, Constant White, Schwerspatweiss, Barytes

Barium Sulphate— BaSO_4 .

Obtained by grinding the mineral *heavy spar* (natural sulphate of barium), or by precipitation of a soluble barium salt with sulphuric acid (or with any soluble sulphate salt). A much finer and purer product is obtained by precipitation, which when thoroughly washed and dried, constitutes one of the most permanent and unalterable pigments.

Unfortunately Barium Sulphate, as an oil color, has very little covering and tinting power and is, therefore, more frequently used as a water color.

Owing to its high specific gravity and lack of opacity it is very often employed as an extender in heavy paints, greatly increasing the weight and reducing the color strength of the paint.

Many organic dye-stuffs are precipitated on Barium Sulphate to form the respective Lake Colors.

Barium Sulphate is an important constituent of Lithopone.

Permanent White is insoluble in acids and alkalies and can be heated to glowing without undergoing change. This fact is made use of, in its detection, as it will always remain as an insoluble residue in acid or alkaline solutions of pigments. When heated with carbon, Permanent White is converted into barium sulphide, which if then moistened with hydrochloric acid will evolve hydrogen sulphide.

PRUSSIAN BLUE

Bleu de Prusse, Bleu di Prussia, Azul de Prusia, Preussischblau, Paris Blue, Chinese Blue, Milori Blue, Bronze Blue, Steel Blue, Mineral Blue, American Blue

Ferric Ferrocyanide— $\text{Fe}_4[\text{Fe}(\text{CN}_6)]_3$.

Prussian Blue, which was discovered in 1704 by Diesbach in Berlin, is a complex compound of iron and cyanogen. Cyanogen is composed of carbon united with nitrogen— CN —and is known to constitute one of the most powerful poisons, when in the simple compound potassium cyanide— KCN . Prussian Blue is, however, non-poisonous.

When solutions of *yellow prussiate of potash* (*Potassium ferrocyanide*)— $\text{K}_4\text{Fe}(\text{CN})_6$ —and iron (*ferric salts*) are brought together (keeping the iron salts in excess) Prussian Blue (ferric ferrocyanide) is formed as a deep blue insoluble precipitate. If during precipitation the potassium ferrocyanide is kept in excess, a deep blue precipitate is also formed which is soluble in water. This compound is composed of iron, cyanogen and potassium and is **Soluble Prussian Blue**.

By treating the insoluble Prussian Blue with *Glauber Salt* (*Sodium sulphate*) and *Oxalic Acid* a soluble Prussian Blue is also obtained.

Ferrous salts, for instance *iron vitriol* (*ferrous sulphate*) and *yellow prussiate of potash* form a white pre-

cipitate, which when exposed to air, or if treated with Nitric Acid, is oxidized, thereby developing Prussian Blue. Owing to the cheapness of iron vitriol (*copperas*) this method is usually employed for the commercial manufacture of Prussian Blue.

Chalk, Gypsum, Clay, Starch, etc., are often added to Prussian Blue as adulterants and also to lighten the color and weaken its tinting strength, an example of which is **Antwerp Blue**.

Prussian Blue is a very transparent color of powerful tinting strength. The best varieties are insoluble in water, of exceedingly hard structure, having a bronzy appearance when dry.

Prussian Blue, when thoroughly pure and washed free of any soluble salts, can be considered among the best pigments, although as a water color, if exposed to direct sunlight, it shows a tendency to fade slightly, but regains its former depth if placed for a time in the dark. Prussian Blue can be mixed with practically all durable pigments, excepting those of alkaline character, which tend to destroy the color.

Lyes (caustic soda or potash) decompose Prussian Blue, yielding potassium or sodium ferrocyanide in solution and red-brown ferric hydroxide as insoluble residue. If this alkaline solution of potassium or sodium ferrocyanide is filtered off and then treated with hydrochloric acid and iron chloride then added, Prussian Blue is again formed (detection of Prussian Blue).

Owing to its sensitiveness towards alkalies, Prussian Blue cannot be employed in fresco or mineral painting.

Weak Acids do not affect Prussian Blue.

By roasting Prussian Blue it is oxidized to brown iron oxide and is known then as *Prussian Brown*.

Solutions of *red prussiate of potash* (*potassium ferrocyanide*) — $K_2Fe(CN)_6$ — when added to solutions of fer-

rous compounds, yield a blue insoluble precipitate, *ferrous ferricyanide*— $\text{Fe}_3[\text{Fe}(\text{CN})_6]_2$, Turnbull's Blue.

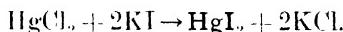
Blue Prints owe their color to the formation of Turnbull's Blue.

PURE SCARLET

Royal Scarlet

Mercuric Iodide— HgI_2 .

This pigment of opaque, beautiful scarlet-vermilion hue, is used principally as a water color, but is rapidly coming into disuse, owing to its lack of even reasonable permanency. It is prepared by the double decomposition of solutions of mercuric chloride and potassium iodide.



Pure Scarlet is entirely soluble in a solution of potassium iodide (yielding a colorless solution).

• RAW SIENNA

Terre de Sienne, Terra di Siena, Tierra de Siena,
Röhe Sienna

A natural variety of Ochre.

Raw Sienna is a very richly colored variety of Yellow Ochre, obtained principally from Toscany. The earth is carefully selected, ground and washed and is then offered as a pigment of considerable transparency and color strength, working well as an oil and water color and equally well in other painting techniques, having the same chemical and physical properties and absolute permanency as all other pigments, common to the ochres.

The large percentage of iron hydroxides present in Raw Sienna produces the rich transparent yellow color, for which this pigment has been prized by artists since ancient times.

RAW UMBER

Cyprus Umber, Turkey Umber, Terre d' ombre,
Terra d' ombra, Tierra de sombra, Umbra

A variety of ochre obtaining its color from the presence of iron hydroxides and the oxides of manganese.

The better kinds of Umber are native of the Island of Cyprus. The native earth is washed, finely ground, levigated and after thoroughly drying, constitutes one of the most durable and permanent pigments, adaptable to all painting techniques.

Raw Umber does not react with other pigments in mixtures. True Umbers are insoluble in alkalies.

When roasted or calcined the iron hydroxides lose their water constituent, being converted into red oxide, the pigment is then known as **Burnt Umber**.

When Umbers are treated with warm hydrochloric acid, chlorine gas is evolved, easily recognized by its characteristic disagreeable and piercing odor.

REALGAR

Arsenic Orange

Arsenic disulphide— As_2S_3 .

Realgar (like *Orpiment*— As_2S_3) is a sulphide of arsenic of orange-red hue. Also like *Orpiment* it is an unstable pigment in mixtures, very poisonous and not permanent to light, soluble in potassium sulphide, and sodium bicarbonate.

Realgar was used in very early times as a pigment and mentioned by Pliny, A.D. 77.

RED LEAD

Minium, Orange Mineral, Saturn Red, Paris Red,
Rosso di Saturno, Minio, Mennige

A bright red oxide of lead— Pb_3O_4 .

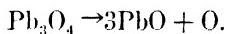
When litharge (lead monoxide— PbO) is heated in presence of air, it gradually oxidizes to the higher oxide— Pb_3O_4 —known then as **Red Lead**.

The finest variety of Orange Mineral is obtained by carefully heating pure White Lead, which is thereby converted into Litharge and then into Red Lead.

Red Lead in dry powder form, soon turns black upon exposure to light. This darkening is perhaps due to a reduction of the red lead to lead monoxide and dark brown lead peroxide = $\text{Pb}_3\text{O}_4 \rightarrow 2\text{PbO} + \text{PbO}_2$. This reaction is not produced by oxidation, as it will occur in a vacuum tube exposed to light. When the pigment is ground in an oil or resin, this darkening does not readily take place. As an oil color, Red Lead is fairly permanent to light. Like all pigments containing lead, it is very sensitive to sulphurous gases (characteristic formation of black lead sulphide). When ground in linseed oil, Red Lead hardens readily, yielding a quick-drying color. Owing to its exceptional covering and weather-resisting properties, it is used frequently as a heavy-paint for underpainting on metals, as a protection against rust.

Mixtures of White Lead and Orange Mineral fade upon exposure to light. Certain other colors, Cadmium Yellow, etc., are readily acted upon by this pigment.

Upon strongly heating Red Lead, oxygen is given off, with formation of reddish-yellow litharge =



Dilute Nitric Acid decomposes this pigment to lead nitrate (in solution) and dark brown lead peroxide. This reaction yielding the dark brown peroxide, distinguishes Red Lead from pigments of similar color, such as Vermilion, Chrome Red, Cadmium Red, etc.

Red Lead was known to the ancient Romans and Greeks as **Minium**, latin for vermillion. Vitruvius and Pliny both make reference to it.

REUBENS MADDER

A lake of beautiful orange-brown hue, prepared from the Madder root. Lately a better and more permanent product is obtained for the coal-tar alizarin.

ROMAN OCHRE

A variety of natural ocherous earth, selected for its high color value and possessing the permanent and durable physical and chemical properties of the Ochres.

ROMAN SEPIA

A mixture of Sepia and Burnt Sienna, to obtain a warm sepia hue, with chemical and physical properties common to Sepia and Bt. Sienna.

ROSE CARTHAME

The coloring principal of this transparent brilliant lake color is derivative of Coal Tar. It is a modern pigment with good permanency to light, with chemical and physical properties common to the lake pigments.

ROSE DORÉE

A variety of Rose Madder of more scarlet hue, possessing the physical and chemical characteristics of the Madder Lakes.

ROSE PINK

A fugitive lake of dull rose-red color prepared from Brazil wood, insufficiently permanent for artists' use.

ROUGE

A variety of *ferric oxide* - $2\text{Fe}_2\text{O}_3$.

Obtained by calcining ferrous sulphate. Used as a metal polish and pigment.

SAFFLOWER RED

Rouge végétal, Rosso vegetale, Rojo vágetal,
Safflorrot

A modern lake pigment of good permanency to light, the coloring principle of which is derived from coal-tar.

The true Safflower Red is obtained from the dried petals of *Carthamus tinctorius*, native of Asia and cultivated in most other countries.

Safflower contains two coloring principals, **Safflower Yellow**, soluble in water and **Safflower Red**, also called **Rose Carthame**, only slightly soluble in water. As a dye, Safflower Red is fugitive and expensive. The modern derivatives of coal-tar, yield lakes of much greater permanency and similar hue.

SAFFRON

Crocus

A bright yellow obtained from the saffron plant, *Crocus sativus*, native of the Orient. Saffron is principally used today as a coloring for confectionary.

SAP GREEN

Vert de vessie, Verde veseca, Verde vejiga,
Saftgruen

An inspissated extract of unripe buckthorn berries, of dark yellow-green hue, not very permanent, readily imitated in hue by the more permanent coal-tar lakes.

True Sap Green is only used as a water color, not working well as an oil color, and is valued as glazing color, being very transparent.

SCARLET LAKE

Laque écarlate, Lacca scarlatta, Laca escarlata,
Scharlachrot

Scarlet Lake, like Crimson Lake was formerly prepared from cochineal (see Carmine) in the same manner as Carmine Lake, but this color is imitated, in hue, by the modern permanent Alizarin Madder, toned with a permanent yellow to obtain a scarlet hue, and as such is a very desirable transparent lake, with considerable permanence.

SEPIA

Sepia is obtained from certain species of cuttle fish (or ink fish) *Sepia officinalis*, *Sepia loligo*, etc., common in the Mediterranean sea. The sepia fish have a peculiar gland, which secretes a deep blackish-brown fluid, used by the fish for purpose of defense, its escape being facilitated when the surrounding water is rendered opaque by the dark fluid.

The ink bag is carefully dried, dissolved by alkalies, which only dissolve the color, leaving any particles of the skin of the bag undissolved and after filtering, the color is precipitated upon the addition of acid (usually hydrochloric acid). After thoroughly washing and drying, it yields a pigment of considerable color strength, with good permanency to light and durability in mixture with other stable pigments.

The chemical composition of Sepia is not generally known, its solubility in alkalies and precipitation by acids, gives it the character of a weak organic acid.

Solutions of Sepia in ammonia water or alcohol are sold as Liquid Sepia. Sepia is insoluble in water.

Sepia is only used as a water color, mixtures of Bt. Umber, or Vandyke Brown, with Lamp Black are used in oil to imitate Sepia.

Sometimes Umbers are used to adulterate Sepia, which are usually detected upon calcination. The Sepia, being organic, will leave but a trace of ash, the earthy umber being unaffected.

Warm Sepia, Roman Sepia and tinted Sepias are varieties of mixtures of Bt. Sienna, Alizarin Madder, etc., with Sepia.

SMALT

Zaffre, Royal Blue, King's Blue, Dumonts Blue

Essentially a silicate of potassium and cobalt.

Smalt is the oldest of the blue cobalt pigments, having been discovered about the middle of the sixteenth century by the glass-maker Christian Schuerer in Bohemia.

Smalt is a Cobalt glass, which is obtained by fusing cobaltous oxide together with potash and silica, producing thereby a deep blue colored glass, which is then finely ground and washed. The degree of fineness to which the pigment is ground, produces paler hues. The rougher the pigment, the deeper the blue, but the very coarse-grained product is unsuitable as a pigment.

Smalt has little covering power, is weak in tinting strength and is reacted upon by moisture and the carbonic acid present in the air, becoming lighter and more gray in color.

Smalt is partly soluble in hot hydrochloric or sulphuric acid (with yellow-green solution) but only slightly reacted upon by cold hydrochloric or nitric acid. Caustic alkalies do not affect smalt.

Smalt differs from Cobalt Blue, in that it fuses to an almost blue-black glass bead when strongly heated. Acids detect Ultramarine, gypsum or clay, as adulterants.

TERRE VERTE

Green Earth, Terre de Verone, Veronese Green,
Veronese Earth, Terre verte, Terra verde,
Tierra verde, Gruenerde

A natural earth pigment of ochre character, varying in composition, in consequence of which some Terre Verte pigments differ in hue. The best variety, of deep olive-green color, is found at Monte Baldo, near Verona, from which source it obtains the name Veronese Green or Veronese Earth.

Terre Verte is a product of natural disintegration of certain minerals and is composed generally of the silicates of iron and other elements. The iron silicate is the coloring principle. The best varieties are selected, treated with dilute hydrochloric acid to remove any calcium carbonate (whiting) or ochre and after thoroughly washing, are ready for use.

Terre Verte is a very dependable pigment for use in oil and water color painting. It is semi-opaque and of weak tinting strength. Some varieties of Terre Verte become discolored (of rust color) when used with the calcium hydroxide employed in true fresco painting (formation of iron hydroxide).

When calcined, Terre Verte is converted into an ochre-brown color, which is then known as **Burnt Terre-Verte**, and as such is a very permanent and durable pigment.

Terre Verte is sometimes imitated or adulterated by mixtures of Yellow Ochre and Prussian Blue. Alkalies destroy the Prussian Blue in such mixtures, turning same brown in color. Water, alcohol or weak ammonia water is used to detect the addition of dyes. Ammonium hydroxide will turn Terre Verte blue if any copper colors have been used to brighten the color. Green Ultramarine as a substitute for Terre Verte is readily detected by hydrochloric acid, with formation of hydrogen sulphide.

TRANSPARENT WHITE

A gelatinous transparent mass consisting of alumina ground in oil, used only to extend or reduce the tinting power of lake colors.

ULTRAMARINE

Lapis Lazuli Blue, Bleu d' Azur, Outremer,
Oltremare, Ultramar, Lasurstein, Ultramarine
Ash, Cendre d' outremer, Cenere d' oltremare,
Ceniza de ultramar

The stone Lapis Lazuli from which the genuine Ultramarine is obtained, was known to the Romans and Grecians, as *Saphir* (*Sapphire*) but mention of its use as a source for the pigment, dates between the thirteenth and fourteenth century. The finest varieties of Lapis Lazuli are found in Tibet. It also comes, varying in purity and color, from Siberia, Persia and China.

The natural Ultramarine is usually found to have gold-like specks, consisting of *iron-pyrites*, FeS_2 , (*Fools' gold*) scattered throughout the mineral.

The mineral is essentially composed of silicon, aluminum, sodium, sulphur and oxygen. The molecular construction (chemical formula) of the compound is not definitely known. It is a most peculiar fact, that such a strong color should be produced from a compound of elements which of themselves have no color (with exception of sulphur, which is yellow).

The method of extracting the blue color from the stone consists in selecting the purest pieces, which after having been finely ground, levigated and washed, are kneaded together in the form of a dough (with a little wax, rosin and linseed oil) in a weak solution of potash or soda lye. The finest particles of the color are withdrawn by the alkaline water and settle out when left standing. The dough retains the foreign mineral substances (gangue).

The second and consecutive extracts from the same dough become more gray in color, the first extraction is of the purest and deepest blue color, the last extraction, blue gray in color, contains much gaugue and is the least valuable. These last extractions are known as the **Ultramarine Ash**.

Genuine Ultramarine is permanent to light, moisture, unaffected by hydrogen sulphide and stable in mixture with other durable pigments. Its chemical properties are similar to those of the artificial ultramarines.

ARTIFICIAL ULTRAMARINE

French Blue, French Ultramarine, New Blue,
Permanent Blue, Oriental Blue, Gmelins Blue,
Guimet's Blue, Bleu d' Azure, Ultramarine Red,
Ultramarine Violet, Ultramarine Green, Silver
Ultramarine, Ultramarine Yellow

A blue substance noticed in 1814 as a blue coloration, accidentally produced in the soda furnaces of St. Gobian, France, was subsequently shown to be identical to the lapis lazuli blue in chemical and physical properties.

In the year 1826 Guimet in France, discovered a method for artificially preparing Ultramarine and was awarded 6,000 francs by the Société d' Encouragement de France as a prize for devising a method of artificially producing ultramarine for less than 300 francs per kilogramme. Contemporaneously Gmelin of Tuebingen also published a method of manufacture.

The three principal Ultramarines are the **Soda Ultramarines**, low in sulphur content and of pure blue color; **Soda Ultramarines**, high in sulphur content, of deepest blue color, with reddish tinge and having the greatest power of resisting alum, in consequence of the high silica content also present; **Sulphate Ultramarines** of greenish tinge and the palest in color of the ultramarines and weakest in their power to resist solutions of alum.

The soda ultramarine is prepared by finely grinding a mixture of sodium carbonate, china clay or clays of similar composition, sulphur and a small amount of carbon, in the form of charcoal, pitch, colophony, etc., and strongly heating in closed crucibles or muffle furnaces. The blue formed directly in this process varies in color depending on the amounts of sulphur and silica, which yield deeper and more reddish ultramarines when present in larger amounts.

In order to produce the sulphate ultramarines a mixture of sodium sulphate (Glauber's salt), china clay and carbon are heated to glowing; a reduction of the sodium sulphate to sodium sulphide is brought about by the carbon, and a compound of green color is formed. This is known as **Ultramarine Green**. This Ultramarine Green is then thoroughly washed, after which it is again roasted in a regulated air supply with addition of sulphur, becoming thereby gradually converted into a rich blue color, identical to the soda ultramarines.

Carefully prepared pure Ultramarine Blues rank as most permanent and durable pigments. Genuine Ultramarine is slightly more transparent as an oil color, than the artificial ultramarines, but otherwise next to impossible to distinguish chemically, from the decidedly less in cost, artificial product.

The commercial acid-proof ultramarine is not truly acid resistant, but gets this name owing to its property of resisting the action of alum, due to an excess of silica in its composition. Alum in solution shows acid reaction. This property comes into consideration where the blue is used as a coloring for paper, sugar, fabric, soap, etc.

When ultramarine in oil is applied in heavy application (impasto) some varieties show a tendency to go blind, becoming gray in color with age; this is known as the "*ultramarine sickness*." This phenomenon is fortu-

nately very rare and never occurs when white has been mixed with the ultramarines.

Ultramarine is an absolutely permanent pigment under all conditions of painting, perfectly fast to light and air, stable in mixture with all other durable pigments (discoloration would show one of the pigments to be impure or improperly washed).

Weak and strong organic and mineral acids, except carbonic acid, readily decompose ultramarines, destroying the color with evolution of hydrogen sulphide. Alkalies have no action on this pigment. Alum reacts more readily on ultramarines with low silicate content. The color is not readily destroyed by heat. The addition of dyes to brighten the color is readily detected by shaking a sample of the pigment with water or alcohol, the ultramarines being insoluble. Caustic alkalies will discolor ultramarines to brownish hue if Prussian Blue is present. Ammonium hydroxide will produce a blue solution if copper blues are present. Gypsum, barium sulphate, chalk, china clay, magnesium carbonate, etc., are sometimes added to cheapen the product, which may greatly reduce the tinting strength of the color.

Ultramarine Violet and **Ultramarine Red** are obtained by treating the blue pigment with sal ammoniac and dry hydrochloric acid gas at a high temperature. Properly washed, these colors form permanent pigments, however, of no practical commercial value.

The ultramarine red is converted into **Ultramarine Yellow** when treated with hydrochloric acid gas, at temperatures above 360° C. **Yellow Ultramarine—Silver Ultramarine**—is also obtained by replacing the sodium constituents of ultramarine, with silver. If instead of silver, other elements are used, ultramarines of various colors are obtained, *i.e.*, with zinc a violet; potassium or lithium a blue; barium a yellow-brown; manganese a gray. The

sulphur constituent of the ultramarine may also be replaced by selenium or tellurium, forming brown and violet ultramarines. These compounds are, however, useless as pigments.

The finest varieties of Ultramarines were formerly obtained principally from France, but in recent years this pigment has been developed in the United States and unequalled in purity and color by any of the foreign brands.

VANDYKE BROWN

Cassel Earth, Cassel Brown, Cologne Earth,
Terre cassel, Bruno Vandyck, Pardo Vandyck

These colors are all natural earth pigments, which, coming from various localities, differ accordingly in color and composition. They are all essentially composed of bituminous matter, consequently of organic origin, containing also a percentage of iron oxides and other earthy substances. Vandyke Brown is considered to be a kind of decomposed, soft earthy lignite, receiving its name as a pigment after the famous artist, who was particularly partial to the use of browns in his pictures.

The general composition of Vandyke Brown may be said to be about:

80 per cent. organic matter and moisture.

20 per cent. mineral matter { Oxide of Iron and Alumina
 { Carbonate of lime
 { Insoluble siliceous matter

Vandyke Brown fades upon exposure to light, developing thereby a cold gray tone, this taking place more rapidly when used as a water color than an oil color, in which latter vehicle it is slightly soluble.

This color has little covering power and is a slow drier in oil.

When heated in a test tube a tarry sublimate is produced, leaving a charred residue.

When calcined in presence of air a residue of reddish-brown gray ash remains; showing considerable loss of weight by ignition (contrast true Umbers). Most of the organic constituents of Vandyke Brown dissolve in caustic alkalies, to a deep brown solution.

Many pigments are offered today on the market as Vandyke Brown, which are varieties of dark brown iron oxides, or calcined brown ochres and as such, of course, are very desirable colors for permanency and durability.

VERDIGRIS

Vert de gris, Gruenspan, Verdet de Montpellier

Several acetates of copper are constituents of Verdigris, the most important of which is the blue variety, a dibasic acetate and the green verdigris, a mixture of the di- and tri-basic acetates.

The blue verdigris is produced by allowing copper plates to be acted upon by the vapors of acetic acid (vinegar) in presence of air. Great quantities of this pigment are made at Montpellier, France, where sheets of copper are placed in loose piles of spent wine lees, or the marc of grapes, when these evince a strong vinegar odor. The vinegar fumes gradually react with the copper and when conversion has taken place sufficiently, the verdigris is scraped from the plates, mixed with water and formed into balls.

Distilled or crystalline verdigris is of dark green color, crystalline in structure and is essentially neutral copper acetate— $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{H}_2\text{O}$, which owing to its solubility in water and transparency, is of little importance as a pigment.

Verdigris should not be employed as an artist's pigment, being the most fugitive of the copper greens, unsafe in mixtures with most pigments of organic origin and lake colors and also affecting some mineral pigments. As a

water color it is not durable, readily affected by moisture. In oil it shows better permanence but only when well protected by a strong film of oil or varnish. In oil, the color with age becomes slowly darkened and more green in hue, being acted upon by the fatty acids. It is only slightly soluble in water, readily soluble in all acids, without effervescence. Heated with strong sulphuric acid it evolves acetic acid. When strongly heated it turns black (formation of copper oxide). Hydrogen sulphide or sodium sulphide, blacken Verdigris (formation of black copper sulphide). An excess of ammonium hydroxide gives a deep blue solution (characteristic test for detection of copper). Adulterations with Prussian Blue, or dyes, may be detected in the usual manner. Verdigris is used principally for the manufacture of Emerald Green.

Pliny, A.D. 77, mentions that this color may be prepared from copper and vinegar. Verdigris was known to the ancient Romans and Grecians.

VERMILIONS

English Vermilion, French Vermilion, Chinese Vermilion, Orange Vermilion, Scarlet Vermilion, Cinnabar, Quicksilver Vermilions, Sinopis, Vermilion, Vermiglione, Bermellon, Zinnober

All hues are pure *mercuric sulphide* -HgS.

Vermilion is a compound of mercury and sulphur found native as the mineral *cinnabar* (*mercury blend*) in Spain, China, Japan, Mexico, Peru, Germany, Austria and California.

The natural mineral is rarely found sufficiently pure and bright in color, to be used as a pigment. Vermilion is manufactured directly from the elements mercury (*quicksilver*) and sulphur, by what is known as the *dry method* and the *wet method*.

In the dry method, the raw materials are used in the

dry condition; 84 parts by weight of mercury are intimately mixed with 16 parts by weight of sulphur, until an amorphous black powder (*Ethiop's mineral*) is formed, from which the crystalline vermilion pigment is obtained by sublimation. The *Ethiop* is pure mercuric sulphide and is unchanged chemically during the sublimation process; a change of color, entirely due to a physical change (molecular rearrangement), having taken place.

The Vermilion obtained in this manner, is then treated with hot alkaline solutions, in order to remove any free sulphur; after which it is thoroughly washed, yielding a much brighter and purer color than when the washing is omitted. The more finely this crystalline Vermilion is ground, the resultant color will vary from a dark red to light red hue.

In Holland the dry method is said to have been employed for several centuries. It was also usual, in Holland, to add about $2\frac{1}{2}$ percent of red lead or finely divided metallic lead to the mercury and sulphur.

In the year 1687, G. Schulze published the first process for preparing Vermilion by the wet method and today there are great number of such processes in use.

In the wet method, the quicksilver and sulphur are ground together, in the presence of water; after which the black compound is constantly stirred for many hours with a warm solution of caustic potash or potassium sulphide, until it develops the desired vermilion color. It is then thoroughly washed and dried. By varying the process somewhat, it is possible to obtain vermiliots of different hues, however, all chemically composed of mercuric sulphide.

For some inexplicable reason, certain varieties of vermilion darken upon exposure to strong sunlight (revert to the black amorphous condition), this being especially evident when the pigment is impure. Those colors ob-

tained by the dry method and the native product, usually show greater stability under exposure to direct sunlight. Vermilions inclining towards a bluish tinge usually show greater permanence than those of an orange and scarlet hue. Vermilions, which for centuries had retained their red color in illuminated books and manuscripts, have been known to darken when placed in museums, where they were subjected to direct sunlight.

As an oil color, pure Vermilion, where properly protected by a film of oil and varnish, may be accepted as permanent, if not exposed to direct sunlight.

Vermilion, if overglazed with alizarin madder⁶ is very unlikely to undergo any change in color. Vermilion is very opaque, of scarlet color and is one of the heaviest pigments (in specific gravity). The pigment does not require much oil as an oil color, is a slow dryer as such and must be very carefully ground in order to prevent separation of the oil from the pigment.

Impure air, sulphurous gases or moisture have no affect on Vermilions. They are very stable in mixtures with all other durable pigments. Only when impure or containing free sulphur will Vermilions discolor White Leads.

Pure vermilions are insoluble in water, alcohol, alkalies or in dilute acids. Nitric acid does not react with vermillion, presence of red lead shows brown discoloration. A solution of sodium sulphide, with addition of a small quantity of sodium hydroxide, will dissolve vermillion very readily. Dyes (usually Eosine) are readily detected with water, alkalies or alcohol, the liquids becoming colored in their presence. Heated, a change in color takes place, from bluish to brown and eventually to black, if still further heated the mass will burn with bluish flame, leaving only a trace of ash; if impure or adulterated with such substances as red lead, iron oxides, barytes, etc., these will remain as residue. Sodium sulphide will

only blacken vermilion which are adulterated with red lead or chrome yellows. A mixture of nitric and hydrochloric acids will dissolve vermillion to a colorless solution (of mercuric chloride).

Red lead and *scarlet antimony sulphide* (**Antimony Vermilion**) are principally used as adulterants, some inferior brands, also, have the addition of eosine, or some other fugitive dye-stuff, to brighten their color.

Antimony Vermilion is a fugitive color, acted upon by dilute acids and alkalies, and blackens when gently heated.

Vermilions were used from very earliest times; 400 years B.C. the Egyptians were known to have employed it as a pigment. The schaschar of the ancient Hebrews was vermillion and is said to have been used as early as 600 years B.C. It is, also, thought to have been known to the Assyrians and even to the Chinese at a still earlier time. Pliny, 77 A.D., refers to it as "minium," which name is now given to red lead.

VIOLET CARMINE

The source of color for this semi-transparent lake pigment varies. Some Violet Carmines are prepared from the root of the *Anchusa Tinctoria*, others from Brazil wood and some are mixtures of Alizarine Madder with Cobalt, or some other durable blue. Only the latter product would possess sufficient permanency to be of value to the artist.

WHITE LEADS

Cremnitz White, Flake White, Lead White, Silver White, Dutch White Lead, Blanc d' Argent, Blanc de Plomb, Bianco di piombo, Blanco de plomo (albayalde), Bleiweiss, Cerussa Alba, Ceruse, Kremser Weiss, Blanco de Cremnitz

Basic lead carbonate— $2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$.

The native carbonate of lead was known to the ancient Romans and Grecians as *cerusse*. Theophrastus, Pliny and Vitruvius mention its preparation from lead and vinegar. After the fall of the Roman Empire, it was prepared first at Venice, later at Crems in Austria, then in Holland, England, Germany and France. Today the United States is one of the largest producers of White Lead.

There are many processes by which White Leads are made, but great quantities are still produced by the oldest method, the **Dutch Process**, in which carbon dioxide, oxygen (of the air) and water vapor (moisture), react on metallic lead in presence of acetic acid fumes (vinegar). In this method (which if properly conducted yields an excellent product) these reactions are brought about by stacking clay pots, containing dilute acetic acid and flat metallic lead buttons, buckles or coils, in tiers and covering them with fermenting tan bark, spent tan or fermenting dung; which latter during decomposition evolve carbon dioxide and considerable heat, thereby evaporating the acetic acid, forming *lead acetate* (*sugar of lead*) on the surface of the lead, which in turn is converted into White Lead by the carbon dioxide. The Old Dutch process, when carefully and properly carried out, yields a very fine product, more or less crystalline in structure. Great quantities of White Lead are still made by this process, even though about 90 days are required for complete corrosion.

In some of the newer processes, for instance the *quick process*, heated vapors of dilute acetic acid and carbon dioxide act upon atomized metallic lead, blown with steam into large revolving wooden cylinders; thereby producing White Lead of more amorphous character, less crystalline in structure than the Dutch lead.

In the *mild process*, finely divided metallic lead powder is thoroughly mixed with air and water, forming a basic

hydroxide of lead, which is then acted upon by carbon dioxide gas to form White Lead. In this process no acids, alkalies or other chemicals are required.

Some processes bring about conversion by precipitation from solutions of basic lead nitrate with carbon dioxide.

There are any number of different processes used in the manufacture of White Lead, the various products differing somewhat in chemical and physical composition, but all are essentially basic carbonates of lead. In this connection Cremnitz White differs from Flake White and these again from Dutch White Lead.

A good variety of White Lead should be composed of about 70 per cent. carbonate of lead and 30 per cent. lead hydroxide. The varying percentage of lead carbonate and hydroxide affect the opacity, consistency and durability of the pigment.

Finely ground White Lead should be washed free of any uncombined sugar of lead, the presence of which will impair the stability of the pigment.

White Lead is one of the most opaque white pigments, being equaled in this respect only by Permalba, and like all pigments containing lead, it is very sensitive toward hydrogen sulphide, rapidly becoming discolored brown and black (formation of black lead sulphide).

As an oil color it becomes somewhat yellowish in color, upon ageing, some varieties also become less opaque (formation of lead soaps with the acid constituents of the oil). Pure White Lead in oil when exposed to the elements, becomes chalky after long exposure. These changes are especially evident with White Lead containing sugar of lead or with those higher in lead hydroxide content. White Lead has always been considered a durable and permanent pigment when properly employed, showing the greatest stability when protected by a strong oil or varnish film, from influences of hydrogen sulphide

and other destroying components of impure atmosphere. Its solubility in sodium chloride soon causes disintegration of the pigment when exposed to sea air. Carbon dioxide in the air also gradually attacks White Lead.

White Lead is seldom used in water color painting, and not at all in Fresco or Mineral Painting, as in these techniques it is insufficiently protected and discolors very readily in consequence. In oil, it is one of the quickest driers, requiring only a small amount of oil. Mixtures with most organic colors, lakes and certain few chemical colors are best avoided as being of questionable durability. The sulphide colors, such as the Cadmiums and genuine Vermilions in mixture with pure White Lead are perfectly durable (discoloration would indicate one of the colors to be impure, presence of free sulphur or improperly washed, etc.). Permalba, is rapidly taking the place of White Lead on the artist's palette, due to its desirable physical and chemical properties, greater opacity, tinting strength, durability and stability in mixture with all other pigments.

Acids decompose White Leads with effervescence, due to evolution of carbon dioxide.

Dilute Nitric or Acetic Acids dissolve White Lead entirely with evolution of CO_2 gas, any insoluble residue would indicate adulteration with barytes, clay, silica, etc. Barytes is principally used, as it is specifically heavy; clay, gypsum, whiting, etc. are also frequently used. Water dissolves gypsum from White Lead, which is then readily detected as described under Gypsum (page 62). Whiting is also easily detected by thoroughly washing a sample of the White Lead in question, with water and treating the washed pigment with very dilute sulphuric acid, thereby converting the White Lead into insoluble lead sulphate and any whiting (calcium carbonate), if present, into calcium sulphate. The filtrate is then tested

for gypsum' (calcium sulphate) as described under gypsum.

Hydrogen sulphide, or a solution of sodium sulphide, decompose White Lead with formation of black lead sulphide.

When heated, White Lead loses carbon dioxide and water, being slowly converted into lead oxide— PbO , known as *litharge*, yellowish-red in color. *Massicot* is also a modification of lead oxide, pale yellow in color, obtained in the same manner. By prolonged heating, the lead oxide thus formed, combines with additional oxygen, forming the bright red oxide, known as *minium*— Pb_2O_4 . When heated with carbon, White Lead becomes yellow in color and upon further heating it is converted into metallic lead.

White Lead is insoluble in water and any sugar of lead (*lead acetate*) if present, is brought into solution, the detection of which may be made by adding sodium sulphide (formation of black lead sulphide in presence of lead in solution) or by sulphuric acid (formation of insoluble white lead sulphate).

Hydrochloric acid precipitates insoluble lead chloride from solutions of White Lead, which precipitate is soluble in boiling water.

Sodium carbonate precipitates lead carbonate from solutions of White Lead.

Caustic soda dissolves White Lead.

Upon the addition of potassium bichromate to a neutral solution of White Lead, a yellow precipitate of insoluble **Chrome Yellow** (*lead chromate*) is formed.

White Lead which has become discolored, is bleached (oxidized) to white lead sulphate, when treated with *hydrogen peroxide*— H_2O_2 .

White Lead is a cumulative poison.

A cheap substitute for White Lead is sometimes found to be *basic lead chloride*— $PbCl_2 \cdot Pb(OH)_2$ which is not

durable in mixtures. It is readily detected by its solubility in hot dilute nitric acid, without effervescence. If, to such a solution, the addition of a drop of silver nitrate forms a white flocculent precipitate, this would indicate the presence of the chlorine ion (see page 167).

Other White Lead pigments used principally in heavy paint manufacture are **Sublimed White Lead**—*Basic Sulphate White Lead* formed by oxygen (in the air) during the roasting and subsequent volatilization of galena. It is a very stable, fine, amorphous pigment, considered non-poisonous.

Zinc Lead White composed of equal parts of zinc oxide and lead sulphate is obtained from the reduction, volatilization and subsequent oxidation of zinc and lead ores containing sulphur.

Neutral Lead Sulphate— PbSO_4 is but seldom used as a pigment and should not be confused with the basic lead sulphate.

WHITING

Cale-spar, Paris White, Chalk, Marble Dust,
Gilders White, Spanish White, Whitening, English
White, Blanc de Menden, Blane Mineral

Calcium Carbonate— CaCO_3 .

Whiting is chiefly prepared from chalk, which occurs as a soft rock principally in England. Some very fine deposits have also been found in the United States. The natural calcium carbonate is found in abundant quantities in nature.

Whiting is of organic formation, consisting of the calcareous parts of minute organisms, known as *Foraminifera*. Egg shells, oyster shells, coral, and pearls are other varieties of organic origin. Iceland spar and calcite are pure forms of crystallized calcium carbonate. Marble is a distinctly crystalline variety, lime stone a more compact, less crystalline variety of calcium carbonate.

The preparation of Whiting is a very simple procedure, the crude rock is crushed and then finely ground under water (known as the *leveigation process*). Water is added and after thoroughly agitating, the mass is passed through a series of tanks, in which the heavy particles settle in the first tank (yielding **Commercial Whiting**), the finer particles settle in the second tank (producing **Gilders White**) and the very finest sediment, obtained in the last tank, yields **Paris White**. **Bolted Gilders Whiting**, is whiting, which has been bolted through very fine bolting cloth.

Whiting has very little opacity in any medium and is seldom used as an Artists' Pigment, being used principally as an adulterant, sometimes also as a base for lake colors.

Putty is a mixture of whiting and linseed oil.

Whiting and glue size were used for Italian and Spanish tempera painting-grounds, sometimes with addition of plaster of Paris.

Drawing chalk and *pastels* are usually prepared of calcium carbonate, altho most *black-board chalk* is composed of gypsum.

Whiting is unaffected under ordinary atmospheric exposure. Sulphurous gases do not affect it. In acids, Whiting is entirely soluble with strong effervescence (due to evolution of carbon dioxide) to a clear solution; any insoluble residue would indicate the presence of impurities, such as sand, clay, etc. Traces of iron cause Whiting to be of cream color.

If heated too strongly, when being dried, small quantities of quick-lime - CaO, are formed which give the Whiting an alkaline reaction.

Whiting may, also, be made artificially, by precipitation from solutions.

YELLOW LAKES

Dutch Pink, Italian Pink, Yellow Madder, Yellow Lake, Brown Pink, Stil de Grain Brun, Quercitron, Laque de gaude, Yellow Carmine, Lacca gialla, jaune, Laca amarilla

A series of yellow lakes in which the coloring principle is of organic origin, precipitated on a base of Alumina, or Whiting, etc., to form the corresponding lake pigment. All of these yellow lakes are not permanent to light and are mostly very slow driers in oil.

The principal substances from which the dyes are extracted, are : Quercitron bark, the bark of several species of North American oak trees; Persian, Turkish or Avignon berries; species of buckthorn (*Rhammes*) and from other plants such as the weld (dyer's weed), etc.

The richer yellow lakes prepared from a deep variety of Quercitron bark and sometimes also from Turkish or Avignon berries are called **Italian Pink, Dutch Pink, Stil de grain brun** and **Yellow Madder**.

Brown Pink is a deep variety of Quercitron lake.

To make these lakes, the berries or sections of bark are ground into small pieces and the dye extracted by boiling in water. The water is then filtered off and treated with a solution of Alum, to which a solution of Soda is added to yield a precipitate of Alumina, which carries down the dye, during precipitation, to form the respective lake pigment. The bases are varied accordingly by manufacturers, to prepare different hues and commercial qualities.

These yellow lake pigments were known in the time of Pliny, A.D. 77.

The colors are now imitated by using some of the very permanent and alkali-proof yellow lakes, which are products of the modern chemical color industry and should be used by the artist in preference to these very fugitive

older yellow lakes. The newer colors are excellent transparent colors for overglazing and when used, as such are very brilliant and permanent.

The organic yellow lakes char to a white ash and are decomposed by hydrochloric acid yielding a deep yellow solution, any insoluble residue consisting of barytes, clay, etc., which was used as the base of the lake pigment.

ZINC WHITE

Zinc Oxide, Chinese White, French Zinc, Blanche de Zinc, Snow White, Bianco de Zinco, Blanco de Zinc, Zinkweiss

Zinc Oxide— ZnO .

Zinc had made a place for itself in European art before it was recognized as a distinct element or as a metal, e.g., it is found to exist as a component in the implements and weapons of the Bronze Age. In somewhat later times it occurs as an alloy with copper and tin in rings, bracelets and other ornaments of personal adornment which are found in ancient burial mounds of Germany and Denmark.

The Romans were the first manufacturers of real brass—an alloy of Zinc and Copper. While they did not know anything about Zinc as such, they had discovered that by melting copper with a certain ore (*Calamine*—hydro-silicate of Zinc) a yellow alloy of more golden color than Bronze could be obtained (*Bronze* is an alloy of copper and tin).

This yellow metal—*Brass*—was first employed for coins during the reign of the Roman Emperor Augustus about 20 B.C.

Zinc as a distinct metal was unknown in early times, in fact, as late as the sixteenth century it was not known in Europe, but there are strong reasons for believing that the Chinese were acquainted with it as a metal at least several centuries earlier. According to some of the

early records the Dutch captured a Portuguese ship with a cargo of Zinc, in the early part of the seventeenth century. This was supposed to have come from China, as the Chinese were known to possess considerable metallurgical knowledge. However, not until early in the eighteenth century was sufficient interest manifested in the metal to endeavor to produce it from ore. A tradition recorded by Berkman, says that an Englishman visited China to learn the art of making Zinc. He attained his object, returned with the secret and soon afterwards a Zinc plant was erected at Bristol, England, for the production of *Spelter*. This plant was erected in the year 1743.

Shortly after the establishment of this Spelter plant at Bristol, the Spelter produced was used to coat iron sheets to prevent them from rusting. This was ordinary *galvanized iron*. The operator of this process noticed that a fine white powder collected about the edges of his melted zinc bath. This proved to be Zinc Oxide, and for some time after this, the Zinc Oxide available for testing purposes, was collected from the edges of galvanizing baths.

The commercial production of Zinc Oxide as a pigment was started in France in the latter part of the eighteenth century by Leclair and Sorel. Leclair was a paint grinder and master painter. He made some elaborate and conclusive tests with Zinc Oxide as his pigment. This gave him a whiter and more desirable paint. Investigations of Leclair's claims, by the French Government, led it to specify Zinc Oxide in all Government work. Later White Lead was prohibited above certain percentages and Zinc Oxide specified in its place.

The Zinc Oxide used by Leclair was made by burning spelter with an excess amount of air. The plant he erected and used was still in operation up to the breaking out of the world war. The process he used is known as

the *French Process*, or *indirect process*, since in its operation, spelter or Slab Zinc must be produced from the ore and then burned in a special furnace to produce the oxide.

The manufacture of Zinc Oxide in America is connected with some of the early endeavors of the New Jersey Zinc Company to solve the problem of using successfully the complex refractory and then little known ores, from the famous Franklin mine.

The Zinc mines at Franklin, N.J., were discovered in the latter part of the eighteenth century, by a party of Swedish miners who were traveling overland from Baltimore to New York. The earliest record we have of this deposit of ore, however, is 1824, when some of the minerals occurring there were described by Messrs. Vanuxem and Keating. The first mining that was done at Franklin was at the time when the United States Government made its standard weights and measures (1838). It is said that the Government imported workmen from Belgium, built a spelter furnace at Washington, and made the zinc that was needed for the brass of these standard units of weight and measure, from ore from Franklin, with some scattered boulders of zinc ore found in Sparta Valley and from ore from Perkiomen, Pa. The old pit from which this ore was taken was known as the "Weights and Measures Opening" and was in existence until about 1900, when the mining operations caused its disappearance. Real mining operations did not begin at Franklin, however, until about 1850.

In the *French Process* the zinc ores are smelted, the zinc being distilled off and collected as molten zinc. The metallic zinc is cast in slags which are again melted in a different kind of furnace and the melted zinc upon further heating vaporizes. The fumes upon meeting the air, burn with a bright greenish-yellow flame to Zinc Oxide, which after cooling is blown through large pipes and collected. It is then sampled, graded, and packed, ready for use.

In order to insure uniform products, great technical skill is required in operating this process.

It is only since the development of Zinc Whites, especially in the United States, that the true chemical and physical properties of Zinc Oxide have become recognized, with respect to its durability as an artists' pigment. The use of Zinc Oxide for artistic purposes only dates back to about the middle of the eighteenth century and up to within comparatively recent years many foreign and some domestic brands were principally responsible for the lack of confidence sometimes placed in pure Zinc White. Even today some brands of Zinc White are offered in a very impure condition, containing lead and a comparatively high proportion of water-soluble salts. It is clearly obvious that such an impure pigment would greatly reduce the durability of the color, especially when ground in oil, and impair the stability of mixtures with other pigments.

Tests made with the highest grades of American-made French Process Zinc Oxide, have shown the highest stability in mixtures with other durable pigments. This was not found to be true of impure Zinc White.

The American-made French Process Zinc Oxides are usually found to be of the most reliable, the various brands being carefully kept up to the required standard, ranking highest in whiteness of color, permanence, fineness, durability and inertness toward other pigments in mixtures, showing no tendency to chalk, crumble or become transparent.

Pure Zinc White is a durable pigment in all painting techniques. It possesses exceptional tinting strength and produces true tints of high color value.

As an artists' color pure Zinc White in oil grinds to an excellent buttery consistency. It dries more slowly than Lead White.

Weight for weight or volume for volume, Zinc Oxide

has greater hiding power than White Lead. Owing to its extreme fineness and to the fact, that it requires more oil than White Lead, Zinc Oxide paints can be brushed out much thinner than White Lead paints.

Zinc White, when painted impasto, tends to become hard and seale, but where applied in thin application this property is reduced to a minimum. A mixture of Zinc White and Permalba forms a most durable oil color, the hardness of the aged Zinc White film being counteracted by the more pliable aged Permalba oil film.

Some varieties of impure Zinc White contain basic carbonate of zinc, which causes the pigment to lose some of its opacity. Basic carbonate of zinc is occasionally used as an overglazing color, but its use as an artists' pigment is not advisable, where permanency is of first importance.

Zinc White is insoluble in water, oil, alcohol or turpentine and remains unchanged by exposure to light and air. The formation of basic carbonate of zinc from zinc oxide, by the carbonic acid gas in the air, is usually over-exaggerated, this conversion seldom taking place to any appreciable degree, especially with Zinc White in oil, where the pigment is properly protected by a strong oil or varnish film from atmospheric influences.

Sulphur gases, hydrogen sulphide or sodium sulphide do not discolor Zinc White, the zinc sulphide when formed being as white as the oxide.

When heated, Zinc White turns yellow, but upon cooling turns white again. Lead White, when heated, changes to yellow lead oxide.

In dilute acids (Nitric Acid, Hydrochloric Acid, Sulphuric Acid, also in Acetic Acid) Zinc White is soluble without effervescence, yielding colorless solutions. Sodium hydroxide or potassium hydroxide will precipitate white gelatinous zinc hydroxide from these solutions, which is soluble in an excess of the reagent.

Dilute sulphuric acid should completely dissolve Zinc White without effervescence, a property not possessed by any other white pigment. Effervescence would indicate the presence of White Lead, whiting or magnesite. Most other adulterants would remain as insoluble residue (barytes, clay, silica, etc.). The acid solution, when treated with an excess of ammonium hydroxide, upon the addition of ammonium sulphide should yield a white precipitate of zinc sulphide. A discolored precipitate would indicate the presence of other metals.

Zinc White is, also, soluble in ammonium hydroxide and alkaline solutions.

Zinc Oxides are classified as follows:

French Process Zinc Oxide—*White Seal, Green Seal* and *Red Seal*—used chiefly for artists' colors and enamels.

American Process Zinc Oxide, lead free—used chiefly for paint and rubber goods.

U. S. P. Zinc Oxide—used for pharmaceutical preparations.

Leaded Zinc Oxides, 5 per cent. to 35 per cent. basic lead sulphate, are used chiefly for heavy paints.

ZINC YELLOW

Citron Yellow, Zine Chrome, Jaune de zinc,
Giallo di zineo, Amarillo de zinc, Zinkgelb

Zinc Chromate— $ZnCrO_4$.

Commercial Zinc Yellows vary considerably in composition, the carefully prepared chemically pure variety showing exceptional permanence to light and air, while the impure products lack dependable stability in this respect.

Pure Zinc Yellow is very stable in mixtures with other durable pigments, mixtures with lakes and certain organic colors are best regarded as of uncertain stability. It is employed only as an oil and water color.

Most dilute acids readily dissolve Zinc Yellow. Hydrogen sulphide does not discolor or blacken this pigment (contrast with Chrome Yellow). The same chromic acid reaction with alcohol and hydrochloric acid is obtained as with Chrome Yellows, Strontium and Barium Chromate (see page 187, test for chromate radicle) and no precipitate is formed upon addition of sulphuric acid to the solution. Alkalies in excess readily decompose Zinc Yellows, yielding yellow solutions. Zinc Yellow is also dissolved by ammonia. Heat destroys this pigment.

Zinc Yellow has been used as an artists' pigment only in comparatively recent years.

COLOR THEORY

Color is not a substance, but a product of partial or selective absorption, or transmission of irregular or scattered reflection, or of dispersion in refraction of white light. Sunlight, which we recognize as white light, is a compound of many rays of varying vibrations, that is of many colors all blended together so that the eye distinguishes but one kind. If however this light is made to fall on a glass prism, it is bent or refracted and the mixture is broken up. We obtain instead of the white light, which enters the prism, an elongated band of different colors. This dispersion, when of a sunbeam, produces what is termed the solar spectrum.

The prismatic spectrum is composed of a series of colors, arranged in similar order to those of the rainbow. Each color vibration of different wave length, is refracted to a different degree; thus the rays of shorter wave length, such as that of a certain tint of blue measuring one fifty-five thousandth of an inch is more refracted than that of a certain tint of red having a wave length of one thirty-thousandth part of an inch.

The colors of the spectrum blend one into the other and although we might name a hundred different colors in the spectrum, each a different color sensation absolutely, we cannot however accurately distinguish such fine divisions with the eye and ordinarily for convenience, divide the spectrum into seven regions, as follows; Red, Orange, Yellow, Green, Blue, Indigo, and Violet.

Beyond the visible spectrum at the violet end we have another set of rays which are more highly refracted, of very small wave length and are known as the ultra-violet or chemical rays.

Beyond the red end, there are also invisible less re-

fracted rays of greater wave length, known as the dark, heat, or ultra-red rays.

Upon careful study it was found that the solar spectrum is crossed by a vast number of dark lines, called Fraunhofer's lines after Fraunhofer, who early in the nineteenth century showed that when a solar spectrum is produced in such a manner that the colors are sharply separated, these lines are visible. Through the use of the spectroscope, an instrument invented by Bunsen and Kirchoff, to produce and view the spectrum, it was found that white light from an incandescent solid gives a continuous spectrum. Light however coming from incandescent vapors, yields a spectrum consisting of a series of bright lines; for each element the color and position of these lines will differ. By analysis of the spectrum produced by the vapor of a substance it is possible to discover of what element it is composed, such minute quantities as 1/3,000,000 milligram of sodium being detectable by means of the spectroscope.

Artists finding that by skillful use of three colored pigments, red, yellow and blue, nearly all the hues or tones of colors can be obtained, accept these three colors as the primary colors.

By a *primary color* we understand a color which cannot be produced by the admixture of other colors.

A *secondary color* is one produced by admixture of any two primary colors.

A *tertiary color*, or better termed a *triad*, is one which is produced by the admixture of any two secondary colors.

The above terms are exceedingly arbitrary and consequently not very scientific, as will be shown later on. However, at present we will only consider the primary color sensations red, yellow and blue, as pertaining to the admixture of colored pigments.

Any two colors are said to be *complementary*, to each

other, when the product of their combinations in proper proportions produce the sensation of white light on the retina of the eye. We can very easily illustrate this by the use of Maxwell's rotating color disc, which is a round disc on which two complementary colors are placed in proper proportion and rapidly revolved about an axis through its center. The two complementary color sensations will fall in rapid succession on the same parts of the retina of the eye and will become blended into one, which will appear as a gray. This gray must be accepted as white, due to the loss of considerable white light in reflection. When using colored beams of light the resultant sensation will be white. In like manner, if on a circular cardboard we paint the seven principal spectral colors and rotate the same very rapidly round its centre axis, the result will be the same as mentioned above when complementary colors were taken.

The study of the *contrast of color* is a very important subject and reference should be made to any authoritative work on color in which this subject is given in detail. The three principal influences which affect the contrast of color, are the difference of *purity*, *brightness* and *hue*.

Two complementary colors of equal purity and brightness when placed in juxtaposition gain in brilliancy without suffering alteration in hue. When one of these colors is not equal in hue, purity, brightness or truly complementary, this difference will be accentuated. If the two adjacent colors are of different hue, this difference is increased, each appearing to have been mixed with the complementary of the other.

The background upon which the colors are examined, if black, gray, white or colored, will also considerably influence the resultant contrast. A simple instance of *simultaneous contrast* is illustrated by examining a strip of color on a black, gray or white ground. On black,

the color seems to gain in brightness; on gray gaining less in brightness depending on the relation between the gray and the color and on the white ground the color appears still less bright than on the gray or black ground. Conversely, if we place a strip of gray on a colored ground, the grey strip appears tinged with the complementary of the colored ground. Thus a gray strip will appear tinged with red when placed on a blue-green ground; and will appear tinged with blue-green if placed on a red ground.

Contrast of tone is readily accomplished by placing in contiguity a series of about five or six toned strips of equal size, the first strip tinted pale gray and each succeeding strip of deeper gradation. It will be observed that the side of each strip lying against the next darker, will appear lighter, due to the contiguity of the darker tone and the series of tones resemble a number of hollows. By substituting tones of any color, this example of simultaneous contrast may be observed in like manner, as with the series of grays.

Colors in which red and yellow predominate are sometimes mentioned as *warm*, or *advancing colors*. Those in which blue predominate are spoken of as *cold* or *retiring colors*. A gray tinged with yellow, orange or red is termed a warm gray, when tinged with blue, a cold gray. A green may be said to be warm, if of yellowish-green hue and cold if bluish-green.

Colors given forth by light rays are called *transient colors*, whereas all others, such as dye, chemical, earth and mineral colors produced by reflection, refraction or partial absorption of light are called *inherent colors*. The inherent colors never approach the transient colors in purity.

The following table will illustrate the principal color sensations:

Primary	Secondary	Tertiary (Triads)
Red 5	Green 11	Russet 21
Yellow 3	Purple 13	Citrine 19
Blue 8	Orange 8	Olive 24

Black contrasts more strongly with *white* than with any color and accepting white as the unit 1, it has been proven that one part white excites the nerve fibrils of the retina of the eye to as great an extent as three parts yellow, etc., while the power of the secondary and tertiary colors will be equal to the sum of the numbers of the colors of the admixture. The numbers designated on the above table of primary, secondary and tertiary colors will illustrate this fully.

The colors are arranged in the above table so that the complementary colors are opposite, for instance; green of the secondary color complements the primary color red, while russet of the tertiary complements the secondary color green, etc.

Every color has three qualities, called *color constants*; (1) *hue*, or *color tone*, the quality by which, for example, bluish-green differs from yellow-green, (2) *value or luminosity*, by which for instance light **green** differs from dark **green**, and (3) *chroma, purity or intensity*, by which, for example a pure or spectral **green** differs from a broken or grayish-green.

A *saturated color* is one as free from white or black as possible.

Tint is the term applied to the resultant admixture of one of the primary, secondary, or tertiary colors with white. Mixed with black in place of white, the result is called a *shade*. Both may be expressed in terms of light, medium and deep, according to the amount of white or black present.

White and black, and grays produced by their admixture are not regarded scientifically as colors. They

are used in the *scale of brightness*. For instance if white is added to a color it is said to brighten it. On the other hand the addition of black or a gray is said to darken it.

A body when illuminated by a white light will appear white if there is equal reflection, and no partial absorption, of the incident rays.

Total absence of light, or equal and total absorption of incident rays by a body, represent darkness or black.

Colors of the primary, secondary and tertiary group are termed *positive* colors, because they do not contain white or black. The tints and shades are classified as *negative* colors.

However, the physicist, who is concerned scientifically with color in reference to light, is not satisfied with the red, yellow, blue, primary color sensation theory. This theory, adapts itself only practically, as a rule for the art of mixing pigments to produce color effects.

Two great physicists, Young and Helmholtz, and other physicists found that nearly all color sensations could be produced in normal eyes by the use of red, green and violet *lights* and their combinations. A certain red, a certain green, and a certain violet, were therefore accepted by them to be the three primary color sensations. A later, more comprehensive theory takes red, yellow, green, and blue as primary color sensations.

These theories account for the non-perception of color in dim light or in very oblique vision, by assigning different capacities to the "Rods" and the "Cones" respectively, of the retina in the eye. These rods and cones are contained in one of the layers of the retina. The rods, according to this theory, convey only the sensation of light without color to the brain and are more easily stimulated than the cones, which are supposed to give the color sensations.

A certain set of these nerve fibrils of the retina are

especially sensitive to its own specific color sensation, namely that set particularly acted upon by such of the longer light waves as those of red color, are but slightly stimulated by the shorter green waves and still shorter violet waves. Color-blind persons are those in whom one or more of the sets of nerve fibrils fail to respond to the incident color sensation.

Fatigue of the retina is easily caused by looking for a short time steadily at a strongly colored object held against a background of gray or white.

The nerve fibrils of the retina which receive the image of the colored object lose for a short time the power to receive the respective color of the object, while their capability of receiving other color sensation is not impaired. If for instance, we look intently at a bright spot of red and then glance at a white surface we will note the spot to appear identical in shape on the white surface, however, in the color complementary to red, *i.e.*, green. After-images due to impressions made on the retina are curious results of looking, for example, at some particular spot on a window with a bright sky as background and then closing the eyes. The image will appear with the eyes closed, with color changes and with details that were not observed with the eye open.

Pigments are only visible by reflected light, each respective pigment obtaining its color from the ray or rays of light that are not absorbed and which are reflected back from the surface, as also from beneath the surface. Thus a body which absorbs the blue, green and yellow rays of the spectrum and reflects the red rays, will appear in that color which we call red. We always assume the incident light to be white when naming the color of any object. A red object when examined for instance in a yellow light will appear quite a dull brown, owing to the small amount of red rays emitted by the yellow light falling on the object, which consequently in turn re-

flects correspondingly few red rays together with a few other colored rays, giving the body the observed dull brown color.

A blue pigment, such as Prussian Blue and a yellow, such as Gamboge, when mixed together in varying proportions, yield beautiful greens. Bright solar spectra beams of blue and yellow when thrown on the same surface will yield white light, not green as we might expect. The greens produced by the admixture of these pigments are due to absorbtions taking place in the blue and yellow pigments respectively. It is the light which escapes absorption by both pigments which gives the resultant green color. In a mixture of these two pigments the particles are situated so closely together, that only a small quantity of mingled yellow and blue scattered light reaches the eye directly, most of the light reflected is green, the Prussian Blue losing nearly everything but the green of which it possesses a quantity, likewise the Gamboge. The remaining light, which both pigments are therefore able to reflect, is green, not as commonly thought, due to the mingling of yellow and blue reflected light. Blue and yellow pigment colors, which reflect unusually small amounts of green light, such as Ultramarine, known to be the purest blue and Cadmium Yellow, a very pure yellow, yield in their admixtures very dull greens.

Most objects become visible by giving off light, which has fallen upon them directly or indirectly, from some light-giving body; very few shine, or are visible, by their own light. Colored transparent objects generally owe their color to the fact, that they are not transparent to all kinds of light. When a compound light such as sun-light shines through a transparent body, some of the rays are absorbed by the body, thereby being usually changed to heat, the reflected and transmitted rays give the body its apparent color. Many transparent substances

have what is termed surface colors. Certain aniline dyes and various other substances will have a decided metallic, or different appearance on their outer surface, due to reflection of rays not penetrating into the body; however, the transmitted rays are usually of strong color. The difference in color of some compact solids and the same in powder form can thus be explained.

Bodies which we cannot see through and that do not appear to transmit light are called *opaque*. Most bodies if in shape of a thin layer or sheet, will no longer be opaque to a strong light. Light penetrates a little distance beneath the surface of opaque bodies, where some of it is absorbed and reflected by the interior particles. These latter or unabsorbed light rays return to the outside, imparting to the object the color by which we know it.

The light reflected from the real external surface of non-metallic colored bodies receiving white light is usually not colored. Certain fabrics, such as silk, illustrate this, reflecting white light from their outer surface together with considerable colored light reflected from the interior. This reflected white light produces what is called the "*sheen*." On account of the considerable amount of white light, thus reflected, mixed with the reflected color of the fabric, in parts, the color of the fabric appears very pale.

Dry pigments in a very fine state of pulverization reflect considerable white light from their outer surfaces. If we reduce the amount of this reflection by wetting the powder with water, or with the more highly refracting oils, a decided deepening of the color takes place. A coarsely ground powder will be more deeply colored than when finely ground. Here the particles are large and the incident light will have penetrated much deeper to undergo a given number of reflections and more light

will be partially absorbed, the greater amount of reflected light making the coarser powder appear deeper in color.

The chemist has made use of the different colors imparted to the colorless flame of a Bunsen burner, when a metal, or salt of the same, is held in the flame attached to a platinum wire; as a means of rough detection of their presence. The flame is colored violet by Potassium; intensely yellow by Sodium; yellowish-green by Barium; crimson by Strontium; yellow-red by Calcium; green by salts of Copper and also Boric Acid. The ever admired colorful pyrotechnic or fire-work display is produced by the skillful use and selection of the above mentioned colored flame reactions.

Usually bodies, which give off light of their own, are exceedingly hot in temperature, however, certain bodies possess the quality of being luminous, without being hot and are said to be *luminescent* in this condition.

Fluorescence is a form of luminescence.¹ When a body gives off light different in color and not a constituent of the incident light, without evidencing a change of temperature it is said to be fluorescent. The name is derived from the mineral fluor spar, which mineral and other substances, such as paraffin oil, kerosene, the solution of Eosine dye in alcohol and others, are highly fluorescent.

Other bodies, without being hot, continue for a time to emit light after having been exposed to light.² These bodies are said to be *phosphorescent*, the name being derived from the element phosphor, which if the surface is fresh, will glow in the dark, in air. With phosphor, however, it is not a case of phosphorescence, but a chemical reaction, that of slow oxidation.

Many substances such as rubies, some diamonds, sulphides of calcium, strontium and barium, and a large

number of inorganic substances, natural and artificial, absorb radiant energy when exposed to the sun, and subsequently emit light rays.

The common lightning-bug, the glow-worm and the luminosity of the sea at night, due to the glow of microscopic living organisms, afford interesting examples of luminescence.



ELEMENTARY COLOR CHEMISTRY

Chemistry is that science which makes study by analysis and synthesis, of the properties and composition of all forms of matter and of the action of substances on each other and the changes in composition, which occur, in consequence.

Through past ages man has observed the material changes constantly taking place in nature, the study of which later enabled him to artificially produce, as also to control many of these changes. It is only, however, during years, comparatively recent, that chemistry has been developed to such a degree, that civilization could never have reached its present height, but for the manifold application of this science in industry.

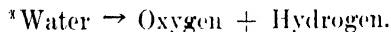
Chemical changes are everywhere taking place about us. When the metal iron is exposed to damp air, we notice a change to take place, namely its conversion into a red powder, which we know as rust. Likewise, when wood burns, being thereby converted into gaseous substances, or fruit juices ferment, there is a change in which each substance has lost its original identity, having been changed into entirely new substances. These are said to be *chemical changes*.

If we bend a rod of iron, make sawdust of a piece of wood, or break a pane of glass into small fragments we have only changed the original size, shape or color of these materials and we say a *physical change* has taken place.

Our mother earth is composed of two kinds of substances, the so-called simple substances; *elements* and *compound substances*.

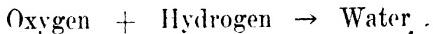
Water, for example, is a compound substance, as it

can be separated into two different substances, both gases at ordinary room temperature—



By experimentation it will be found that one volume Oxygen (or 16 parts by weight) and two volumes Hydrogen (or 2 parts by weight) are obtained when water is decomposed. Such a separation is called an *analysis*.

If we take two volumes hydrogen and one volume oxygen and combine them we will again obtain water.



The combining of these two elements to obtain water is termed *synthesis*.

We have been unable to separate either the oxygen or hydrogen further into other substances and these are, therefore, called simple substances, or *elements*. There have been discovered some eighty-five of such elements, the most important of which are listed on page 148.

At ordinary room temperature some of the elements are in gaseous form, some fluid and others solid.

Most solid substances are made fluid by heating (melting). Fluids are converted into a gaseous condition by heating and so also reversely, when gases are cooled they are made fluid and fluids become solid (freeze) if cooled sufficiently.

If we intimately mix 32 grams[†] sulphur with 200 grams quicksilver by, briskly rubbing the two substances together, we will obtain a black powder, which if properly heated will yield the red pigment Vermilion and it will be found that exactly 232 grams of pigment is obtained. In this instance 32 grams Sulphur + 200 grams Mercury → 232 grams Vermilion.

* → should always be read as *yields* or *forms*.

+ should always be read as *with*.

[†] See tables of Weights and Measures, page 207.

Element	Symbol	International Atomic Weights		Valence	Specific Gravity	
		Approx- imate	Exact		Water = 1	Air = 1
Aluminum . .	Al	27	27.1	III	2.7	
*Antimony . .	Sb	120	120.2	III V	6.69	
*Argon . .	A	40	39.88	—		1.38
*Arsenic . .	As	75	74.96	III V	5.72	
*Barium . .	Ba	137	137.37	II	3.75	
Bismuth . .	Bi	208	208.0	III V	9.74	
*Boron . .	B	11	11.0	III	2.45	
*Bromine . .	Br	80	79.92	I	3.18	
Cadmium . .	Cd	112	112.40	II	8.64	
Calcium . .	Ca	40	40.07	II	1.54	
*Carbon . .	C	12	12.005	IV	(1.75-2.10) (Amor- phous)	
*Chlorine . .	Cl	35.5	35.46	I	—	2.49
Chromium . .	Cr	52	52.0	II III VI	6.92	
Cobalt . .	Co	59	58.97	II	8.72	
Copper . .	Cu	63.6	63.57	I II	8.91	
*Fluorine . .	F	19	19.0	I	—	
Gold . .	Au	197	197.2	I III	19.32	
Helium . .	He	4	4.00	—	—	0.0137
Hydrogen	H	1	1.008	I	—	0.069
*Iodine . .	I	127	126.92	I	4.94	
Iridium . .	Ir	193	193.1	—	22.42	
Iron . .	Fe	56	55.84	II III	7.85	
Lead . .	Pb	207	207.20	II IV	11.38	
Lithium . .	Li	7	6.94	I	0.53	
Magnesium . .	Mg	24	24.32	II	1.69	
Manganese . .	Mn	55	54.93	II IV	7.42	
Mercury . .	Hg	200	200.6	I II	13.59	
Nickel . .	Ni	58 7	58.69	II	8.6	
*Nitrogen . .	N	14	14.01	III V	—	0.967
*Oxygen . .	O	16	16.00	II	—	1.105
*Phosphorus . .	P	31	31.04	III V	(White) 1.8	
Platinum . .	Pt	195	195.2	IV	21.16	
Potassium . .	K	39	39.10	I	0.862	
Radium . .	Ra	226	226.0	—	—	
Selenium . .	Se	79	79.2	II IV	45	
*Silicon . .	Si	28	28.3	IV	2.49	
Silver . .	Ag	108	107.88	I	10.53	
Sodium . .	Na	23	23.0	I	0.971	
Strontium . .	Sr	88	87.63	II	2.51	
*Sulphur . .	S	32	32.06	II IV VI	2.01	
Tellurium . .	Te	127.5	127.5	II IV VI	6.1	
Tin . .	Sn	119	118.7	II IV	7.298	
Titanium . .	Ti	48	48.1	—	4.50	
Tungsten . .	W	184	184.0	—	18.77	
Uranium . .	U	238	238.2	—	18.68	
Vanadium . .	V	51	51.0	—	6.025	
Zinc . .	Zn	65	65.37	II	7.14	

If on the other hand we analyse this quantity Vermilion we will obtain from 232 grams of pigment 32 grams of sulphur + 200 grams of Mercury.

We see from these experiments, that Vermilion like water is a compound substance.

The two constituents of Vermilion, namely Mercury and Sulphur after combining, were found to lose their former identity entirely (color, form, metallic appearance, etc.) a new compound substance being produced. We have here another example of *chemical change*, such as also took place when we synthesized water:

2 grams Hydrogen + 16 grams Oxygen \rightarrow 18 grams Water.

Vermilion is a chemical compound of mercury and sulphur, water a chemical compound of hydrogen and oxygen, neither are merely physical mixtures.

Never more or less than 200 grams mercury combine with 32 grams sulphur; or 2 grams hydrogen with 16 grams oxygen¹:

The ratio between the weights of the hydrogen and oxygen is found to be 1 : 8. Experience has shown, that this relation is unvarying, that every compound has a definite composition by weight. This is known as Dalton's first law, *the law of definite proportions*. We can assign a number to every element, *equivalent or reacting weight*, which represents the number of parts by weight, which unite with, or replace, one part of hydrogen, or its equivalent. If, as often occurs, an element has more than one reacting weight the one will always be a multiple

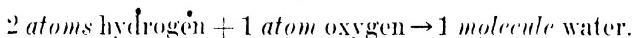
In the list of elements opposite, the exact atomic weight of oxygen = 16.00, this is most commonly used and accepted as standard, making the Hydrogen atom consequently slightly greater than 1.

For convenience in ordinary calculation, the approximate atomic weights may be used.

The elements are classified as metals and non-metals (metalloids). Those elements showing the most marked physical and chemical characteristics of non-metals are marked in the above list with an asterisk.*

of the other. For example it is found oxygen unites with hydrogen in two proportions, in water it is 8 : 1 and in the other compound 16:1. We would never find that in any instance 12 parts by weight of oxygen would combine with 1 part by weight of hydrogen.

This led John Dalton in 1805 to state his *atomic hypothesis*, in which he described all matter as being composed of small particles, which he called *atoms*. These atoms attract or hold on to other atoms, do not break up or subdivide when taking part in chemical reactions, and each atom of any one element is identical to all other atoms of that same element in weight as also in other properties, but different in weight from atoms of any other element. When two or more atoms unite, as occurs in forming a particle of a compound, this group of atoms is called a *molecule*. A molecule can be defined as the smallest particle of a substance, which retains all properties of the mass. For example:



We have found, that 2 grams hydrogen united with 16 grams oxygen yield 18 grams water. As the weight of the hydrogen atom is taken as a unit for comparing the weights of atoms of all other elements, we see, that if the hydrogen atom is expressed as 1, there being two atoms of hydrogen in water, these would weigh 2×1 or 2. The one atom oxygen, which combined with the two atoms hydrogen must therefore weigh 8×2 or 16.

The *atomic weight* of an element expresses the number of times its atom is as heavy as an atom of hydrogen. The atomic weight of an element coincides with one of its reacting weights.

For convenience in writing chemical formulas, reaction of substances, compounds and elements, each element is given a *symbol*. Usually the first initial letter of the name of the element is capitalized. For instance

hydrogen, is represented by the capital letter H, which incidently, also, expresses, that one atom of hydrogen, or one part by weight is signified. Thus O is read to represent 1 atom of oxygen, also, 16 parts by weight of oxygen. In the second column of the list of elements the symbol of each element is given. Where two or more elements have the same initial letter, another letter is added to the initial capital letter, thus C—carbon; Ca—calcium; Cd—cadmium; Cl—chlorine. The names of the elements were not derived scientifically. Some are named after countries or localities, others are of ancient origin, some have received their names from peculiar properties possessed by them, and still others were named by their discoverers. The symbols of the elements are international, being based frequently on their Latin, Greek and English names, for instance

Iron = ferum = Fe
 Silver = argentum = Ag
 Lead = plumbum = Pb
 Mercury = hydrargyrum = Hg
 Carbon = carbo = C

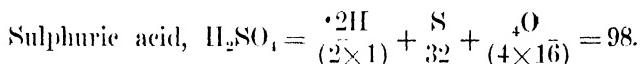
The elements more recently discovered and, which are metals have been given names ending in -ium, those belonging to the non-metals ending in -n or -ne.

We can now read the formula for Vermilion, which we found to be a compound of mercury and sulphur, as HgS . We know the atomic weight of mercury to be 200 and that of sulphur 32, therefore, the combined atomic weights of the two atoms after they have united to form one molecule of Vermilion is 232. This can now be put in the form of an equation:

200 parts by weight Hg + 32 parts by weight sulphur
 \rightarrow 232 parts by weight HgS (Vermilion).

18 parts by weight Water, \rightarrow 2 parts by weight H, hydrogen, + 16 parts by weight O, oxygen.

The weight of a molecule of any substance is the sum of the weight of its constituent atoms:



When there are more than one atom of the same kind contained in a molecule, the number of such atoms is then designated by writing this quantity as a subscript to the symbol. Thus the formula of water is usually written as H_2O and not HOH .

The number of molecules of any one kind is signified by a coefficient, thus three molecules of water are written $3\text{H}_2\text{O}$.

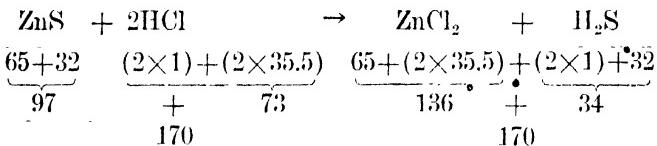
Such materials as solvents (most common of which is water) or catalytic agents (*catalytic agents* are materials, which aid or hasten chemical action but, which, themselves, undergo no permanent change), are not included when writing equations.

Equations can only be correctly written when the composition of each reacting substance and the resultant products are known.

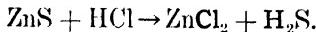
In order to more clearly understand and correctly interpretate a chemical equation we must more closely study the atoms and the part they play in reactions. Any element, which combines with, or replaces, an atom of hydrogen, atom for atom, has a *valence* of one. The atoms of some elements combine with, or replace two hydrogen atoms: it is then said to be *divalent*. Oxygen is an example $\text{H}_2 + \text{O} \rightarrow \text{H}_2\text{O}$. Other elements as Aluminium have a valence of three: AlCl_3 . Some elements, as sulphur for instance, have a valence of two in hydrogen sulphide, H_2S ; in sulphur dioxide, SO_2 , its valence is four, and in sulphur trioxide, SO_3 , its valence is six. The valencies of the elements are given on page 148, in the fourth column opposite each element.

When writing chemical equations, only the symbols of

the elements are used, these symbols then represent definite quantities of all substances taking part in the reaction and *must appear in equal amounts on each side of the equation.* We must *balance* all equations, i.e.,



This equation would be wrong if written:



It should be observed, that equal amounts of Cl and H do not appear on each side of the equation, therefore this equation cannot be correct.

Many equations are *reversible*, that is, certain conditions under which the reaction takes place will permit the reaction to proceed in either direction, it is then written as $A + B \rightleftharpoons AB$. When any one of the substances are removed from the field of action, this prevents the equation from becoming reversible. Ordinarily one of the substances formed is an insoluble precipitate or is eliminated as a gas from the reaction, thereby preventing a reversible reaction.

All chemical reactions can be represented by five equations:

I. DIRECT COMBINATION (Synthesis).

The substances A and B united form AB. $A + B \rightarrow AB$.

II. DECOMPOSITION (Analysis).

A compound substance AB is decomposed into its component substances $AB \rightarrow A + B$.

III. SIMPLE REPLACEMENT.

The compound substance AB is reacted upon by a simple substance C. C has stronger attraction for A than

has B and in consequence will substitute or replace B in the compound AB.



IV. DOUBLE REPLACEMENT (Double Decomposition).

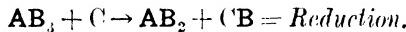
Two compound substances AB and CD react with each other. In this instance A unites with C and B with D.



Double replacements are common in solutions.

V. OXIDATION AND REDUCTION (of little importance in color chemistry).

If the compound substance \mathbf{AB}_3 is treated with the simple substance C, two compound substances $\mathbf{AB}_2 + \mathbf{CB}$ are produced.



When adding D to two compound substances \mathbf{AB}_2 and \mathbf{CB} two compound substances $\mathbf{AB}_3 + \mathbf{CD}$ are produced.

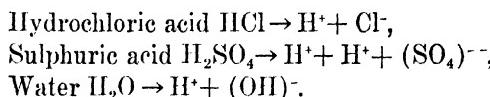


Most chemical reactions take place when in water solution, although the water itself does not react. Water solutions of different salts differ greatly in their power to conduct electric current. *Solutions* are classified, according to their conducting power as *electrolytes* and *non-electrolytes*. Electrolytes are more active chemically than non-electrolytes. If a solution of hydrochloric acid HCl is electrolyzed the hydrogen atoms and chlorine atoms become *dissociated*, and receive opposite electrical charges, \mathbf{H}^+ and \mathbf{Cl}^- . When an atom (or group of atoms) carries an electrical charge it is called an *ion*.

The hydrogen ion carries a positive charge and the chlorine ion a negative charge. Hydrogen and the metallic ions carry positive charges and the non-metallic ions,

negative charges. The number of charges carried by an ion is numerically equal to its valence.

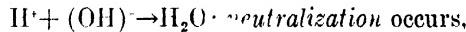
Thus:



Atoms and ions should not be confused with each other. An ion has an electric charge, whereas an atom has not. An ion may also include a group of atoms, in sulphuric acid the two atoms of hydrogen are both ions, but the radicle SO_4 carries two negative charges. A *radicle* is a group of elements which hold together in chemical reactions, acting as if the group were a single element.

An *acid* is a hydrogen compound whose water solution contains hydrogen ions. Every compound in which hydrogen is contained is not an acid, it is only when the water solution of the compound gives hydrogen ions. This hydrogen ion is responsible for the characteristic sour taste and turning of blue litmus to red color. A *strong acid* is one in which the molecules are strongly dissociated into ions in solution. Other acids are termed *weak acids* when their molecules are only slightly dissociated in solution. Like the acids, the strength of the bases is dependent upon the degree of ionization in solution.

Water is practically undissociated and therefore, does not give either acid or basic reaction,



by the union of the positive H^+ ion and the negative $(\text{OH})^-$ ion.

Like charges repel each other, unlike charges attract each other.

It is very important to closely study the names of substances in connection with their reactions, as these will

aid recognition, should explain their composition and the relative proportion of their elements.

When naming a compound substance, the metal constituent if present, is used adjectively with the other component part, to which latter, if the compound is composed of but two elements, *i.e.*, a *binary compound*, the ending -ide is applied. Thus zinc oxide, ZnO, copper sulphide, CuS. When there are two compounds of the same elements, as of mercury and chlorine, where in the one there is a higher chlorine content, namely HgCl₂, the suffix -ic is given, thus mercuric chloride, HgCl₂. In the other compound of these two elements in which the chlorine is less the -ic is replaced by -ous, thus mercurous chloride, HgCl.

Sometimes in order to express proportions or ratios of the element contained in varying amounts the prefixes mon-, di-, tri-, etc., are used, thus carbon monoxide, CO; carbon dioxide, CO₂; sulphur trioxide, SO₃; carbon tetrachloride, CCl₄, etc.

Many radicles are given special names which are used as if the groups were single elements, thus the radicle (OH) is termed hydroxyl; (CN) cyanogen; (NH₄) ammonium. Compounds containing these radicles follow the rule for the naming of binary compounds; thus NaOH = sodium hydroxide; KCN = potassium cyanide; (NH₄)Cl = ammonium chloride.

Compounds containing three elements are called *ternary compounds*. The name of a compound containing three or more elements (or radicles) usually ends in -TE, as sodium sulphocyanate, Na(CN)S; or if all three of the elements are indicated the name may end in -IDE; thus potassium borofluoride, KBF₄. When a third element of the compound is not named it is understood, that this third element is oxygen, thus copper sulphate, CuSO₄, contains copper, sulphur and oxygen.

The name of acids and salts are also given various

endings and prefixes, thus if the acid is a binary compound it follows the rule of naming such a compound, receiving the ending **-IDE**. Thus hydrogen chloride, HCl. When in solution, the prefix **hydro-** and the ending **-IC** is given, as Hydrochloric acid, HCl. The names of the salts of these acids end in **-IDE** having no prefix; thus sodium chloride, NaCl.

When an acid contains oxygen, which is not mentioned in its name, it ends in **-IC**; thus sulphuric acid, H_2SO_4 and when named as a ternary compound the ending **-ATE** is used, thus hydrogen sulphate, H_2SO_4 . The salts of these acids have names ending in **-ATE**, thus copper sulphate $CuSO_4$. Salts containing the sulphate radicle— SO_4 are termed **sulphates**, thus copper sulphate, $CuSO_4$; potassium sulphate K_2SO_4 ; etc.

Acids having a lower oxygen content have the suffix **-OUS**, thus sulphurous acid H_2SO_3 , and when named as ternary compounds receive the suffix **-ite**, as hydrogen sulphite, H_2SO_3 . The salts of these acids end in **-ITE**, as sodium sulphite, Na_2SO_3 .

The prefix **per-** and the suffix **-ic** is used to designate the highest oxygen ratio in any acid thus Perchloric acid, $HClO_4$. The salt of this acid keeps the prefix **per-** and ends in **-ate**, thus sodium perchlorate, $Na(ClO_4)$. The acids with the lowest oxygen content end in **-ous** but have the prefix **hypo-** as hypochlorous acid, $HClO$, named as a ternary compound the prefix **hypo-** is retained, with the ending **-ite**, as hydrogen hypochlorite. Salts of these acids have the prefix **hypo-** and end in **-ite** as sodium hypochlorite.

From the above it is clearly seen how very necessary and important is the correct spelling of chemical names, and under no condition should abbreviation be made.

Consideration will now be given to the most important elements and their compounds; also taking up certain reactions and chemical laws, which will be found of much value and help in studying the pigments.

OXYGEN—O

Oxygen is the most abundant element on the earth, and was discovered in 1774 by Jos. Priestly. Free Oxygen is a constituent of the air. Air is a mixture, composed of about (by volume) 78 percent nitrogen, 21 percent oxygen, and 1 percent argon, carbon dioxide and traces of other substances, the amounts varying slightly in different localities. Water is composed of oxygen united with hydrogen, and in combination with other elements oxygen comprises about one-half of the earth's solid crust. It is also an important constituent of all plant and animal bodies.

Pure oxygen is a colorless gas without taste or odor, slightly denser than air. If cooled sufficiently under pressure, oxygen condenses to a liquid, as do other gases; it can also be solidified by increasing the pressure and by still further lowering the temperature.

Oxygen combines readily with most all other elements to form compounds of these elements, known as *oxides*. When oxygen unites with other elements, termed *oxidation*, this is accompanied by an increase in temperature.

When we breathe, the oxygen of the air causes oxidation to take place within our body, thereby giving the body its temperature; likewise a similar oxidation takes place through the decomposition of organic substances, such as plant and animal matter. At ordinary temperatures oxygen does not readily react with most elements, but with the increase of temperature its action becomes more rapid, accompanied usually by light and heat. When the reaction produces sufficient heat to cause glowing, the temperature at which the substance takes fire is said to be its *kindling temperature*. *Ordinary burning* is therefore an oxidation accompanied by noticeable light and heat. We find, that oxygen is required when most substances burn, and it is therefore said, that this

gas supports combustion. When the heat produced by slow oxidation can not escape and accumulates, thereby rapidly raising the temperature to kindling, spontaneous combustion takes place.

Many elements combine with oxygen in various proportions, thus carbon (C) unites to form CO and CO₂; iron, Fe, → FeO, and Fe₂O₃; sulphur, S, → SO₂ and SO₃, etc.

According to the number of atoms of oxygen in the molecule, these various oxides are called:

Monoxide	CO	carbon monoxide
Dioxide	CO ₂	carbon dioxide
Trioxyde	CrO ₃	chromium trioxide
Tetrachloride	CCl ₄	carbon tetrachloride
Pentoxide	P ₂ O ₅	phosphorous pentoxide

Compounds with lower oxygen content, receive the ending -ous, thus ferrous oxide, FeO; and those of higher content end in -ic, ferric oxide, Fe₂O₃.

Most of the oxides are solid substances at ordinary temperatures, as the oxides of the metals; others are fluid, as water; while still others are in gaseous condition, as the oxides of carbon CO and CO₂, sulphur dioxide, SO₂, etc.

When we burn such materials as wood, coal, oils, etc., we have but little ash remaining. These organic substances, which are mostly compounds of carbon, oxygen and hydrogen yield, upon combustion, oxides in gaseous form, (CO₂ and H₂O) in vapor form). The ash is mostly composed of uncombustible mineral substances.

Ozone is a very active form of oxygen.

NITROGEN—N.

Nitrogen is a colorless, tasteless and odorless gas, slightly lighter than air, of which it is the chief constituent. When cooled to a low temperature under pres-

sure, nitrogen becomes fluid and then solid at still lower temperature, under increased pressure. Nitrogen does not unite directly with but very few elements and at ordinary temperature is indifferent towards almost all substances.

Nitrogen was recognized by Antoine Lavoisier to be an element, during the latter part of the eighteenth century (1772).

The two compounds of nitrogen, **ammonia**, NH_3 and **nitric acid**, HNO_3 , and their several related compounds, will be taken up later.

Nitrogen forms five oxides, the three most important of which are

Nitrous Oxide	N_2O
Nitric Oxide	NO
Nitrogen Peroxide	NO_2

Nitrous oxide N_2O is used as an anesthetic, known as *laughing gas*.

The other oxides of nitrogen are unimportant.

Nitrous Anhydride	N_2O_3
Nitric Anhydride	N_2O_5

WATER-- H_2O .

Water is one of the most abundant compound substances found on the earth, the surface of which is covered over three-fourths by the ocean and everywhere we find water one of the most essential necessities to plant and animal life.

Water freezes at 0°C , solidifies to ice; evaporates at all temperatures, boils at 100°C and if heat is still further applied the water is converted into steam. The unit of measurement for heat is called a *calorie*.†

* The Centigrade measurement of temperature degrees is used throughout this book, except where otherwise designated. (See page 209 for table of conversion of Centigrade ($^\circ\text{C}$) to Fahrenheit ($^\circ\text{F}$) degrees.)

† A calorie is the amount of heat required to raise the temperature

Natural waters are not chemically pure water, as these contain many dissolved substances. *Hard water* is natural water containing large amounts of dissolved substances, *soft water* has very little foreign matter in solution. When water is converted into steam, these substances which were in solution remain as solid residue. The well known boiler scale is an example of such residue.

In order to obtain pure water we *distill* the natural waters. The distillation of water is very easily accomplished, the water is boiled and the steam then led through a cooled tube in which it condenses and drops into the receiving flask as pure water. The solids and liquids which were in solution in the water and which had higher boiling points than the water remain behind. Substances having lower boiling points than water are distilled off before the water. For example in a mixture of alcohol and water, the alcohol would entirely distill off and then with an increase of temperature the water would distill over. We will see later how this distillation plays an important part in the fractional distillation of crude petroleum oils, etc.

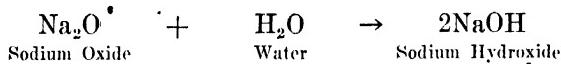
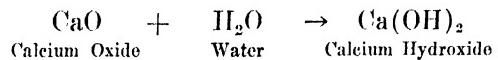
Whenever *water* is mentioned in this book it is understood that only pure distilled water is meant. Distilled water does not leave any residue after evaporation. *Rain water* is natural distilled water, but contains impurities collected from the dust in the atmosphere.

Many substances absorb moisture from the air and are said, therefore, to be *hygroscopic*. Such materials as calcium chloride, caustic potash, lime, sulphuric acid are very hygroscopic and are used often to dry gases or air, for certain purposes.

of one gram of water one degree at 15°C . The British Thermal Unit (B. T. U.) is the corresponding unit of the English system, the heat required to raise the temperature of a pound of water one degree Fahrenheit.

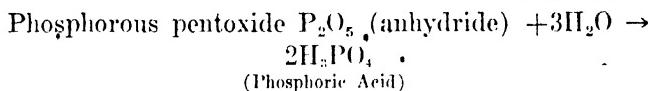
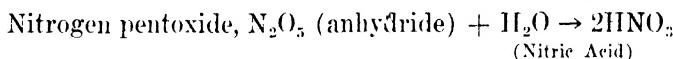
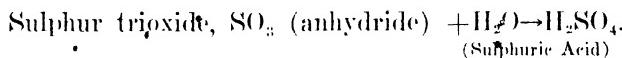
Water combines with many compound substances causing a rearrangement of the atoms.

Many oxides unite directly with water and form the so-called *hydroxides*, also called *hydrates*.



The oxides which with water, form bases are called **basic oxides**. Not all the hydroxides of elements are formed by the action of their oxides in water, but can be prepared in other ways. There exist oxides and hydroxides of most all elements.

Many oxides unite with water yielding solutions, which have characteristic properties in common with acids. These oxides are called *acidic oxides* or *anhydrides* of the respective acid they form, thus



The elements, whose oxides give bases, are called *metallic elements*, those whose oxides give acids are called *non-metallic elements*.

Other well-known acids are:

Acetic Acid $\text{H}(\text{C}_2\text{H}_3\text{O}_2)$ present in vinegar;

Tartaric Acid $\text{H}_2(\text{C}_4\text{H}_4\text{O}_6)$ acidity of wine.

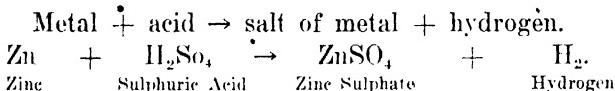
Citric Acid $\text{H}_3(\text{C}_6\text{H}_5\text{O}_7)$ found in the juices of lemons, oranges, limes, and several other kinds of fruits.

Acids are substances containing hydrogen, which may be replaced by metals and whose water solutions have a

sour taste and turn litmus red. Litmus is a blue organic dyestuff, which is used to test for acidity. Paper dyed blue with litmus is changed to red in contact with acids; this red litmus paper is then turned blue when in contact with bases.

Substances, whose hydrogen cannot be replaced by metals are not classified as acids.

If a piece of metallic zinc is placed in a dilute acid (a *dilute acid* is a weakened water solution of an acid) hydrogen is evolved and the zinc is brought into solution. This reaction continues until hydrogen is no longer evolved, the sour taste and the acid reaction on litmus are no longer evident. The acid is then said to have become *neutralized*. If this neutral solution is then evaporated, a residue is obtained, which is termed the *salt of the metal*. A *salt* can therefore be defined as a metal combined with an *acid radicle* (the molecule remaining after the hydrogen has been removed, thus SO_4 is the acid radicle of sulphuric acid H_2SO_4),



The salt is usually found dissolved in water, with which the acid was diluted and receives its name from the acid and metal from which it was formed.

Thus:

Zinc sulphate— ZnSO_4

Silver nitrate— AgNO_3

Lead acetate, etc.

This transposition of the metal with the *acid radicle* is not always possible by direct combination, of the acid with the metal, as certain acids do not react with every metal. This exchange can then be made to take place indirectly.

Salts are solid substances; a number of which are sol-

uble in water, out of which solution they *crystallize*, upon evaporation of the water. Many salts in crystallizing from water solution unite with a definite quantity of water, called *water of crystallization*, which gives shape to the crystal formed. Such salts are often called *hydrates*. Copper sulphate (blue vitriol) contains water of crystallization. When heated the water of crystallization is driven off, changing the blue crystals into a white powder, called anhydrous copper sulphate. A similar salt is washing soda, which if exposed in dry air will lose its water of crystallization, becoming covered with a fine white powder. Such substances are called *efflorescent* which when exposed to air, lose their water of crystallization. Other substances, as we have seen (page 161) absorb moisture from the air and are said to be *hygroscopic*. If they absorb sufficient moisture from the air to cause them to become wet or dissolve, they are said to be *deliquescent* and are, in consequence, often employed as drying agents, for instance to keep the air or gases free from moisture in certain instruments of precision.

All non-metallic elements form acids. The most important are:

- Sulphuric Acid— H_2SO_4 ,
- Nitric Acid— HNO_3 ,
- Hydrochloric Acid— HCl ,
- Carbonic Acid— H_2CO_3 ,
- Phosphoric Acid— H_3PO_4 ,
- Arsenic Acid— H_3AsO_4 ,
- Boric Acid— H_3BO_3 .

Acids of the other non-metallic elements (Silicon, Boron, etc.) and some of the acids of the metallic elements will be taken up later.

SULPHURIC ACID— H_2SO_4 , is a heavy, oily, color-

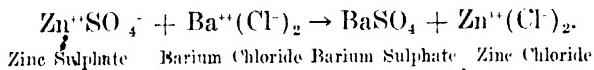
less and odorless liquid, which boils at 338° . The ordinary commercial sulphuric acid, called *oil of vitriol* is nearly twice as heavy as water. Sulphuric acid, especially when concentrated, absorbs moisture from the air, and is in consequence of this dehydrating property, frequently made use of in drying gases, etc.

Many organic substances, such as the skin, wood, paper, sugar, etc. which contain carbon hydrogen and oxygen, are charred by this acid. The hydrogen and oxygen are removed as water H_2O , usually leaving a residue consisting chiefly of carbon.

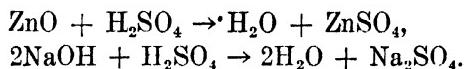
When diluted with water considerable heat is evolved. *It is, therefore, necessary when diluting an acid to always pour the acid slowly into the water, with constant stirring, otherwise if the operation be reversed the sudden generation of sufficient heat to cause steam and spattering will occur.*

Dilute sulphuric acid is less energetic than the concentrated and should always be employed in the laboratory for ordinary reactions, being safe to handle. This is likewise true of nitric acid and hydrochloric acid.

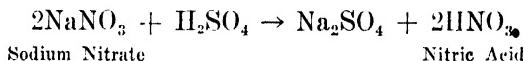
With metals, sulphuric acid forms the corresponding metallic sulphates, the most common of which are soluble, except four viz.: the sulphates of barium, strontium, calcium, and lead. These four insoluble sulphate salts are all important constituents of color pigments. The insolubility of barium sulphate is made use of in the detection of the sulphate ion $-SO_4^{2-}$. A solution of barium chloride when added to a solution of any soluble sulphate salt will precipitate barium sulphate as an insoluble white precipitate, easily identified by its white color, insolubility in water, dilute acids and alkalies.



Sulphuric acid acts as a typical acid with metallic oxides and bases, forming water and sulphates:



Sulphuric acid is employed in preparing many acids from their salts, thus:



The boiling point of sulphuric acid being higher than most common acids, permits the nitric acid formed in this instance, to be distilled off.

NITRIC ACID— HNO_3 , known to the alchemists as *aqua fortis* is a colorless liquid at ordinary temperature, boiling point 86° and is a *very strong acid*, that is when dissolved in water it becomes highly dissociated into ions. Commercial nitric acid slowly decomposes, the solution becoming yellow in color. Nitric acid fumes when exposed to air and has a characteristic piercing odor and even in concentrated form is exceedingly active. The skin, wool and wood are colored yellow by this acid, decomposing these organic substances.

Nitric acid reacts with most metals forming the corresponding metallic nitrate salt. During this reaction poisonous brown fumes of nitrogen oxides are evolved. Nitric acid is also a powerful *oxidizing agent*. It is used extensively in the manufacture of dyes. With organic bases it forms unstable salts and finds wide application industrially. Celluloid is a mixture of nitro-cellulose and camphor.

Certain nitrogen compounds containing carbon, oxygen and hydrogen are exceedingly unstable, forming gaseous products when subjected to even a slight shock. Explosives such as *nitroglycerine*, *gun cotton* and *dynamite* are examples of such unstable nitrogen salts.

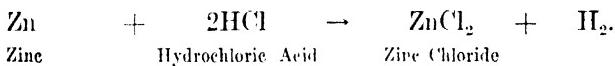
Ordinary *salt peter* is potassium nitrate. *Chile salt-peter* is found in large quantities in Chile and is principally sodium nitrate, from which nitric acid is made. *Calcium nitrate* is a principal constituent of plant fertilizers.

Hydrochloric acid is oxidized by nitric acid, during which reaction *nascent chlorine* is liberated. *Aqua regia* is a mixture of nitric acid and hydrochloric acid. It is used to dissolve gold and platinum.

Hydrogen Chloride—HCl, is a colorless gas, with a sharp penetrating odor, exceedingly soluble in water, the water solution of which gas is commonly known as *Hydrochloric acid* or *muriatic acid*. The high solubility of hydrogen chloride gas is evidenced when the moist breath is blown over the acid, the condensed particles of moisture appearing as a white mist or fume. Concentrated hydrochloric acid when exposed to air, fumes for this reason.

Hydrogen chloride gas when dry, does not show the characteristic acid properties so marked in the water solution of this gas.

Hydrochloric acid does not react with the five metals, mercury, silver, copper, gold, and platinum, but with most other metals it reacts readily, forming the respective metallic chloride salts.



All the common chloride salts are soluble in water, there being three principal exceptions, namely silver chloride, lead chloride and mercurous chloride.

The *test for the chloride ion* Cl^- is based upon the insolubility of silver chloride. If to a solution of any soluble chloride, we add a solution of silver nitrate, a white curdy precipitate is formed, which darkens in the light and which, owing to its insolubility in dilute nitric

acid, is readily distinguished from any other precipitate, which may form. This test, together with litmus paper, serves as a detection for hydrochloric-acid.

Hydrochloric acid is extensively used in the preparation of chlorine from which *bleaching powder* is manufactured.

CHLORINE—Cl, is a typical non-metallic element, in gaseous condition at ordinary temperatures, partly soluble in water, of greenish-yellow color with an intensely disagreeable odor, *exceedingly poisonous*, readily attacking the membrane of the nose and lungs.

Chlorine is used principally for bleaching and disinfecting. *Chloride of lime* (bleaching powder) is a well known disinfectant and bleaching agent, its action being due to the liberation of chlorine, occurring upon exposure to air, or when treated with any common acid. Chlorine does not directly bleach dyes or kill microscopic organisms, but by setting oxygen free, the nascent oxygen becomes the active principle.

Sodium chloride—NaCl, *common salt*, is the most abundant compound of chlorine in nature.

As a group Chlorine, Iodine, Bromine and Fluorine, represent an interesting study. They are known as the *halogens* (salt formers) as they unite directly with a large number of the metallic elements to form salts. Their chemical properties vary in proportion to their atomic weights and classed together, represent a perfect chemical group.

BROMINE—Br, is a dark brownish-red liquid, about three times as dense as water, with a pungent odor resembling chlorine. Bromine unites directly with a number of elements to form the respective bromides. It is of little importance in the manufacture of color pigments, being sometimes used as an oxidizing agent in making certain dyes.

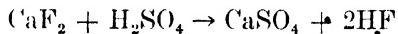
IODINE—I, is a steel gray solid, only very slightly soluble in water, readily soluble in a water solution of

potassium iodide, alcohol, chloroform and carbon disulphide. *Tincture of iodine* is an alcoholic solution of iodine. Iodine vaporizes slowly at ordinary temperatures and when heated, this takes place more rapidly. If the vapor of iodine thus formed, is cooled, the solid element is again obtained. When solid substances can be distilled in this manner they are said to be *sublimed*.

Iodine combines directly with many elements forming iodides. Starch is colored blue in presence of iodine, this reaction is made use of in *testing for either starch or iodine*.

FLUORINE—F, is the most active element known, reacting with practically all substances. Fluorine, at ordinary temperatures, is a gas, almost without color and much more poisonous than chlorine.

Calcium fluoride, *fluor spar*, CaF_2 , is used in the manufacture of opalescent glass. When fluor spar is treated with sulphuric acid, *hydrofluoric acid*—HF, is formed.



This must be prepared in a lead, platinum, or wax dish. The water solution of *hydrogen fluoride*, *hydrofluoric acid*, is used for *etching glass*. Sodium and ammonium fluoride solutions are also used for glass etching. Hydrogen fluoride gas will etch glass to a dull finish, the water solution will leave the etched surface glossy.

Hydrogen fluoride is extremely poisonous and dangerous to handle, causing painful wounds which heal very slowly. A deep breath of the gas may cause death.

CARBON—C, a non-metallic element, which forms numberless compounds with hydrogen, called *hydrocarbons*. Compounds of carbon with hydrogen and oxygen, nitrogen, chlorine, sulphur and other elements are made of special study in the branch of chemistry, called *organic chemistry*.

Carbon is perhaps in many respects, the most im-

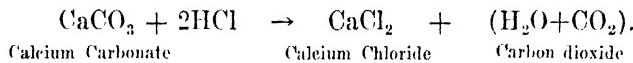
portant element. Both plant and animal organisms contain carbon in the tissues in the form of an organic compound. *Fat* is composed of carbon, hydrogen and oxygen. The muscular tissues of animals is composed of a class of substances, called *proteins* containing carbon, hydrogen, oxygen, nitrogen with a small amount of other elements.

Carbon is found also uncombined, in three *allotropical* forms, as *coal*, *graphite* and *diamond*. None of these forms react with either acids or bases. In nature, compounds of carbon are very abundant as the carbonates of certain metals and also in the air as carbon dioxide, CO_2 .

CARBONIC ACID— H_2CO_3 —is a weak acid, extremely unstable, breaking up into carbon dioxide CO_2 and water H_2O .

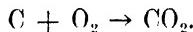


Being a *weak acid*, carbonic acid is readily set free from its compounds by most other acids:



Carbon dioxide— CO_2 is readily prepared by treating a carbonate with an acid. Ordinarily calcium carbonate, the chief constituent of *limestone*, *marble*, *whiting* and *chalk* is used, it being inexpensive and very abundant. Most of the carbonates are practically insoluble in water. The most common soluble carbonates being those of sodium, potassium and ammonia.

Carbon dioxide is also produced in nature by the decay of plant and animal matter, the oxidation going on in animals and plants and during the combustion of all ordinary fuels, which consist chiefly of carbon. The carbon upon burning, combines with the oxygen of the air, forming carbon dioxide:



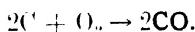
Carbon dioxide is therefore always present in the air. Some natural waters contain considerable of this gas in solution, and unless kept in tightly sealed containers the gas is driven off, the water becoming *effervescent*.

Carbon dioxide is a colorless gas with little taste or odor and is about one and a half times as dense as air. This latter property and the fact that it *does not support combustion* is made use of in extinguishing fires. At ordinary temperatures carbon dioxide is readily liquefied by pressure.

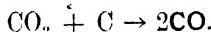
Being a product of complete oxidation of carbon, carbon dioxide is inert towards most other substances.

Carbon dioxide—CO₂, is *not poisonous*, as is the monoxide of carbon—CO.

Carbon monoxide—CO, is an odorless, colorless gas, slightly lighter than air and almost insoluble in water. It is produced by the incomplete combustion of carbon,



The reduction of carbon dioxide:



and by the reaction of steam and red-hot coal



The last method is used commercially in the manufacture of *water gas* of which carbon monoxide is an important constituent.

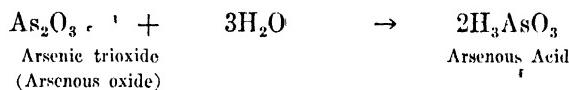
PHOSPHORUS—P, is contained in the bones and teeth of animals, as calcium phosphate. It exists in two allotropic forms, the *white* and the *red*. Phosphorus burns in dry air to phosphorus pentoxide—P₂O₅—producing dense white fumes.

Phosphoric oxide—P₂O₅ combines energetically with water to form *phosphoric acid*, H₃PO₄.

ARSENIC—As, is a steel gray, crystalline solid sub-

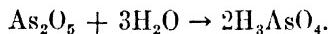
stance with metallic lustre, volatizing with a garlic-like odor. The two oxides of arsenic form acids and like all arsenic compounds, are *very poisonous*.

Arsenous oxide— As_2O_3 , *white arsenic*, is a crystalline powder, slightly soluble in water, in which it forms arsenous acid— H_3AsO_3



Green copper salts of arsenous acid are used as color pigments.

Arsenic pentoxide— As_2O_5 , is an amorphous powder, the water solution of which forms arsenic acid— H_3AsO_4 .



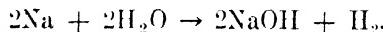
Sulphides of arsenic, As_2S_2 (*realgar*) and As_2S_3 (*orpiment*) are used as color pigments.

METALLIC ELEMENTS

The *metallic elements* have one prominent property in common, in that they replace the hydrogen of acids, forming salts. In other properties they differ considerably.

SODIUM—Na—and POTASSIUM—K. These two metals resemble each other very closely, both chemically and physically. They are both very soft, of silver white color and of very light specific gravity, being only slightly less dense than water. The metallic lustre of these metals rapidly becomes dull on exposure to air (formation of the hydroxide). Sodium and its compounds when placed in a colorless flame (Bunsen burner) impart a very strong yellow color to the flame. Potassium colors the flame reddish violet.

When a piece of these metals is thrown on water, it decomposes the water, thereby liberating hydrogen and forming *sodium hydroxide*, which remains in solution:



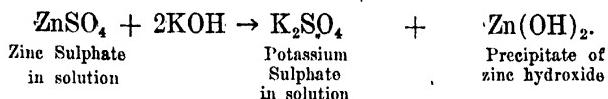
Potassium is slightly more active chemically than sodium:



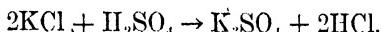
The hydroxides of sodium and potassium (*soda lye* and *potash lye*) are typical bases. They turn red litmus paper blue. Substances asserting this property are said to have an *alkaline reaction*.

Solutions of the strong bases (*caustic alkalies*) sodium hydroxide (*caustic soda or soda lye*) NaOH , potassium hydroxide (*caustic potash or potash lye*) KOH and *ammonium hydroxide* NH_4OH form hydroxides of most metals, from their compounds. Most hydroxides are

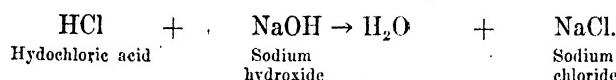
practically insoluble in water and are obtained as precipitates from solutions:



This is an instance of double replacement, the reaction of the base resembling that, which takes place when sulphuric acid liberates weaker acids from their salts:



If a solution of sodium hydroxide and hydrochloric acid contain amounts of each, equivalent to their molecular weights, then this solution will not show either an acid or alkaline reaction. Blue or red litmus paper will not change color when immersed in this solution. The acid and base have lost their characteristic property and form a solution, which we call *neutral*:

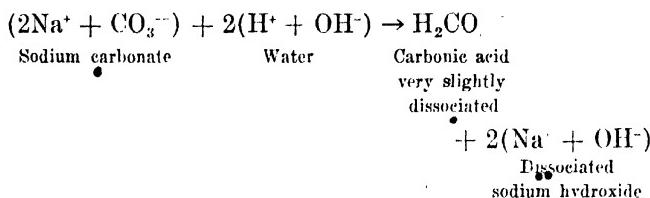


The hydroxide of a metal, or of a metallic radicle, is called a *base* and is not always soluble in water. However, water solutions of bases give alkaline reaction.

The sodium chloride formed in the above equation did not show either an acid or alkaline reaction when in solution. Its solution therefore is termed *neutral*. In this reaction we employed a *strong acid* and a *strong base*, the salt of which, in consequence, has little tendency to combine with the H^+ and OH^- ions of water. All salts of strong acids with strong bases act in this manner.

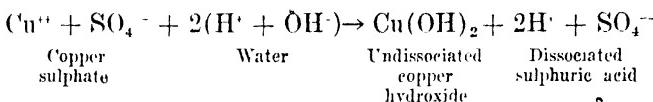
The water solution of a salt such as sodium carbonate, will not react neutral, but shows an alkaline reaction. In this instance, the water of solution has become slightly dissociated, $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$, into hydrogen ions and hydroxyl ions and the sodium carbonate (the product of

a weak acid, carbonic acid H_2CO_3) dissociates into carbonate CO_3^{2-} and sodium ions Na^+ . The carbonic acid which forms, is but slightly more dissociated than the water itself. The sodium ions, Na^+ and the hydroxyl ions, OH^- , remain in solution and are sufficient in number to give a blue reaction with red litmus:



All similar salts formed by *weak acids* and *strong bases* give *alkaline reactions* in water solution. Such a change is called *hydrolysis* and is the reverse of *neutralization*.

Salts formed by *strong acids* and *weak bases* give *acid reaction* in water solution. Here hydrolysis likewise takes place:



Sodium Carbonate— Na_2CO_3 , known ordinarily as *soda* is extensively used, industrially. In the home, it is known as *washing soda* and is the important constituent of *sodium bicarbonate*— $NaHCO_3$, this salt being also used in fire extinguishers.

Anhydrous sodium carbonate— Na_2CO_3 is sold as *soda ash*. When crystallized from water solution it is sold as *washing soda*— $Na_2CO_3 \cdot 10H_2O$. The large percentage of water of crystallization in "washing soda," also called *crystal soda*, is 63 percent, the balance is 37 percent Na_2CO_3 .

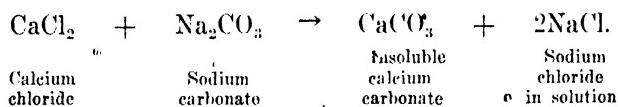
Sodium Sulphate $Na_2SO_4 \cdot 10H_2O$, known as *Glauber's*

salt is an active constituent of medicinal waters and also used extensively in the manufacture of lake pigments.

Potassium Carbonate— K_2CO_3 commonly called *potash*, is generally offered on the market as *calcined potash*. Potassium carbonate is very hygroscopic.

Potash, like soda, is a white substance, readily soluble in water, in which it shows a *basic*, or alkaline reaction.

Various carbonate salts are usually formed by precipitating the respective salt from a solution of a soluble carbonate:



Water glass is an alkali salt of silicic acid.

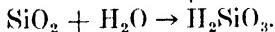
Sodium water glass, sodium silicate, Na_2SiO_3 , and *potassium water glass*, potassium silicate, K_2SiO_3 , are soluble in water, but practically all other silicates are insoluble salts. *Mica*, *talc (soapstone)*, *asbestos*, *feldspar*, *clay*, *garnets*, *meerschaum*, etc., are such insoluble silicate compounds. Mixtures of these compounds comprise *common rocks*, such as *granite*, *slate*, etc.

A solution of water glass, of syrupy consistency, is often used as a *cement*, and to harden such porous materials as *mortar*.

The addition of acids to a solution of water glass, precipitates *ortho-silicic acid*— H_4SiO_4 , as a gelatinous insoluble mass, which if heated is converted into *silicon dioxide*, SiO_2 and water:



Silicon dioxide, SiO_2 is the anhydride of *meta-silicic acid* H_2SiO_3 :



Silicon dioxide, also called *silica*, SiO_2 is the most common compound of silicon, which, next to oxygen, is the

most abundant element in the earth's crust. Silica is harder than glass and insoluble in ordinary reagents. It is found in many varieties, differing in color and structure from the impurities and conditions under which they were formed. The most common form is *quartz*. There are clear crystalline varieties, an example of which is *rock crystal*. *Amethyst* is a purple variety. *Onyx*, *agate*, and *flint* are other forms of silica. *Opal* is a hydrated variety. *Sand* is weather worn silica, produced in fine grains by the disintegration of *sand stone*. Most plants contain silica in their stems. The finger nails, claws of animals, quills of feathers, etc., are composed of considerable silica.

White sand, which is practically pure silica, is used in making glass.

Silica, also called *Silex*, is used, finely ground, as a wood filler and inert extender in heavy paints.

Glass is a mixture of silicates. *Common glass*, *crown* or *window glass* is a mixture of silicates of sodium and calcium. *Flint glass* is composed of the silicates of lead or barium and potassium. When various substances are dissolved in glass, they impart color to the glass. Iron and chromium compounds give green color. Compounds of copper and cobalt give blue color, manganese gives pink to violet, gold a ruby red, silver gives yellow, etc.

Carborundum is the carbide of silicon, silicon carbide—*SiC*, and is used as an abrasive, substitute for emery, etc.

BORON—B, is of little interest as an element, its two important compounds are *boric acid* and *borax*.

Boric acid— H_3BO_3 , also called *boracic acid*, is a weak acid, soluble in water, and used principally as an anti-septic and preservative.

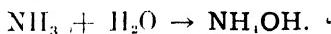
Borax, sodium tetraborate, $Na_2B_4O_7$, is a sodium salt of boric acid. From solution, ordinary borax crystallizes in large clear crystals, with 10 molecules of water of crystallization, $Na_2B_4O_7 \cdot 10H_2O$.

A small quantity of borax when heated on the loop of platinum wire swells during the evaporation of the water of crystallization and then melts, upon further heating, to a colorless glass bead. Many metallic oxides when fused together in this manner, with borax, impart color to the resultant glass bead. Cobalt compounds color the bead blue, manganese compounds impart violet color, chromium a green color, etc. This property is often made use of, in testing for certain elements.

Borax in solution has a weak alkaline reaction.

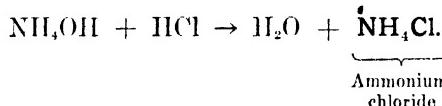
AMMONIUM HYDROXIDE— NH_4OH , ammonia water, is a water solution of ammonia— NH_3 , which is a colorless gas, having a sharp characteristic pungent odor, exceedingly soluble in water, in which it has a strong basic or alkaline reaction (turns red litmus paper blue). Ammonia is, also, produced in plant and animal decomposition.

Ammonium hydroxide, formed by a water solution of ammonia:



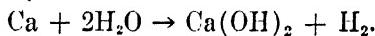
contains the ammonium radicle, NH_4 , and the hydroxyl group— OH .

Ammonium hydroxide, like the caustic lyes, neutralizes acids, forming the respective salts:



Ammonium Chloride— NH_4Cl , commonly called *sal ammoniac*, like other compounds of ammonia, when heated, volatilizes entirely, if the acid radicle is also volatile.

CALCIUM—Ca is a silver white metal, with high lustre and an exceptionally good conductor of electricity. Water is slowly decomposed by calcium, with evolution of hydrogen:



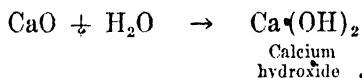
One of the most abundant insoluble compounds of calcium, is **calcium carbonate**, CaCO_3 . *Marble, limestone, calcite, Iceland Spar, chalk*, the mineral matter of shells are all principally composed of calcium carbonate. The impurities contained in limestone, marble, etc. impart the various colors to these substances.

The *stalactites*, which hang like icicles of stone from the roofs of many caves in limestone regions are masses of calcium carbonate; as are also the *stalagmites*, which are the round mounds formed on the floor of the caves.

When calcium carbonate decomposes at a red heat, **calcium oxide**, CaO , (also called *quicklime* or *lime*) and carbon dioxide are formed:



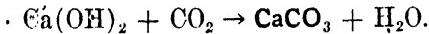
Calcium oxide takes up water, forming calcium hydroxide:



When water is thrown on lumps of quicklime, the mass becomes so hot as to produce steam, swells and then crumples to a white powder. This process is called *slaking* and the calcium hydroxide thereby formed is called *slaked lime*.

Slaked lime is sparingly soluble in water, which solution is called *lime water* and has a strong basic, or alkaline reaction. Lime water, which has undissolved calcium hydroxide particles in suspension, is called *milk of lime*.

Large quantities of lime are used in preparing *mortar*, which is a mixture of sand and freshly slaked lime. The sand becomes enveloped in the jelly-like mass of slaked lime, which, when exposed to the air, takes up carbon dioxide, forming the insoluble calcium carbonate:



Calcium Sulphate— CaSO_4 . When containing two molecules of water of crystallization calcium sulphate is known as *gypsum*, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. *Alabaster* is a variety of gypsum.

When gypsum is heated to 110–150°, three quarters of the water of crystallization is driven off, the residue having one molecule of water of crystallization to every two molecules of calcium sulphate, $(\text{CaSO}_4)_2 \cdot \text{H}_2\text{O}$. The chalky, white powder thus formed is called *plaster of Paris*.

When water is mixed with plaster of Paris, the water is again taken up, forming needles of crystallized gypsum, which set hard and as the mass increases in volume, sharp impressions are obtained of the mould, when the plaster is used for this purpose.

Stucco is a mixture of plaster of Paris and rubble, using glue or sizing instead of water.

Calcium chloride, CaCl_2 and **calcium nitrate**, $\text{Ca}(\text{NO}_3)_2$, are two other important soluble salts of calcium.

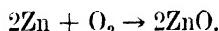
BARIUM, Ba and **STRONTIUM**, Sr, are metallic elements, whose compounds chemically resemble those of calcium.

Barium chloride, BaCl_2 , and **strontium chloride**, SrCl_2 , are white, crystalline salts, soluble in water.

Barium sulphate, BaSO_4 , and **strontium sulphate**, SrSO_4 , are precipitated from solutions of barium chloride or strontium chloride by sulphuric acid. Especially the barium sulphate is characterized by its insolubility in water, dilute acids and alkalies.

Barium hydroxide, $\text{Ba}(\text{OH})_2$ is a water soluble base, with caustic property.

ZINC, Zn, is a bluish white metal, which, when heated in air, burns, forming zinc oxide, ZnO .



Dilute acids react with zinc to form the respective zinc

salts: zinc chloride, $ZnCl_2$, zinc sulphate, $ZnSO_4$, zinc nitrate, $Zn(NO_3)_2$. These three are water soluble salts and are *poisonous*, as are all the soluble salts of zinc.

Zinc is obtained from natural deposits, called **ores**, various metals are extracted from ores. Only very seldom do any ores contain but one mineral. **Minerals** are the elements and compounds comprising the inorganic matter of the earth.

Many *alloys* contain zinc. *Brass* is composed of copper and zinc, *German silver* of copper, zinc and nickel; *bronze* of copper and tin with sometimes an addition of zinc.

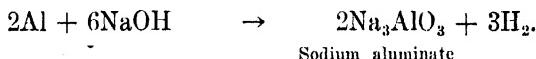
A protective coating of zinc is given iron and this is then known as *galvanized iron*.

ALUMINUM—Al—is a silver white metal, of lighter gravity than any other common metal. Aluminum is not found uncombined but is obtained as such, by *electrolysis*, from its oxide. Aluminum compounds are very abundant in nature. *Rubies*, *sapphires*, *emery*, etc., are more or less pure varieties of aluminum oxide. *Clay* is principally aluminum silicate. When clay (aluminum silicate) and limestone (calcium carbonate) are heated together in proper proportions, to melting, a product which we know as *cement* is obtained. Some deposits of natural limestone contain the proper amount of aluminum silicate and when burned, yield *natural cements*, which were already known and used by the Romans. Cement is supposed to consist of a mixture of calcium silicate and calcium aluminate, which has the property of setting hard, after mixing with water. Cement will set evenly throughout the mass, under water as well as in the air and for years, continues to gain in strength.

A mixture of cement, broken stone, sand and water is used to prepare *concrete*.

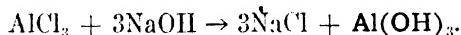
The high metallic surface of aluminum becomes dull on exposure, the result of a thin coating of the oxide. Alu-

uminum remains practically unaltered in air and is not readily attacked by nitric acid or dilute sulphuric acid. Hydrochloric acid reacts with this metal to form aluminum chloride. Sodium and potassium hydroxides dissolve aluminum forming the corresponding aluminates:



Aluminum Sulphate, $\text{Al}_2(\text{SO}_4)_3$ when mixed with potassium sulphate, K_2SO_4 , in solutions of molecular proportions forms the double salt, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ containing twelve molecules of water of crystallization and known commercially as *alum*. In ammonium alum $\text{NH}_4\text{Al}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ the potassium atom is replaced by the ammonium radicle. Chrome alum has the formula $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$.

Aluminum hydroxide— $\text{Al}(\text{OH})_3$, commonly called *alumina*, is obtained as a voluminous, translucent, gelatinous precipitate from solutions of aluminum salts by the addition of an alkaline hydroxide:



Soda, Na_2CO_3 , or *potash* K_2CO_3 , precipitate alumina from solutions of aluminum compounds, with evolution of carbon dioxide, CO_2 .

Alumina is soluble in acids, forming the corresponding aluminum salts and also reacts with strong bases in the manner of an acid (see sodium hydroxide page 174).

When alumina is precipitated in solutions of many organic dyestuffs it has the property of carrying down the color with it, as it settles, leaving the solution of the dye clear. This insoluble, colored precipitate is called a *lake*. Lake colors are used extensively as color pigments and in dyeing. The fibre of some fabrics does not absorb many dyestuffs and it is necessary, therefore, that a substance be used, which will cause the dye

to be indelibly fixed on the fibre. Such a substance is called a *mordant*. Aluminum hydroxide, as also the hydroxides of copper and iron are frequently employed as mordants. Many dyes react with mordants producing different colors.

Aluminum when heated, is converted into aluminum oxide Al_2O_3 :



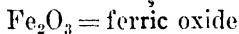
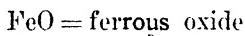
Aluminum oxide is an insoluble compound, found in nature as the mineral *corundum* which when mixed with various other minerals is known as *emery*. It is, next to the diamond, the hardest mineral known and has long been used as an *abrasive*, being more recently displaced by *carborundum*, SiC , which is still much harder. An artificial corundum is known as *alum-dum*.

Crystalline forms of corundum colored blue by traces of titanium oxide are called *sapphires*, other forms colored red by chromium are called *rubies*. Artificial gems are manufactured from fused aluminum oxide. *Red clays*, which are principally composed of aluminum silicate, receive their red color from the presence of iron oxide.

IRON—Fe, is a silver gray metal, readily corroding when exposed to moist air, forming a compound of the oxide and hydroxide of iron, known as *rust*. Commercial iron is classified as *cast iron*, *wrought iron* and *steel*.

Cast iron has the highest carbon content, wrought iron the least, steel usually between the two.

Iron unites with oxygen, to form:



Compounds of iron, in which the ion is bivalent Fe^{++} are

termed *ferrous* compounds, and those where the ion is trivalent Fe^{++} are called *ferric* compounds,

ferrous sulphate— FeSO_4

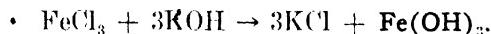
ferric sulphate— $\text{Fe}_2(\text{SO}_4)_3$

ferrous chloride— FeCl_2

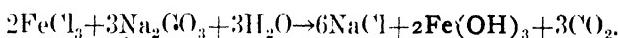
ferric chloride— FeCl_3

The most important compound of iron is **ferric oxide**. The natural earth pigments, *Venetian Red*, *Light Red* and *Indian Red* are colored by their content of ferric oxide. *Rouge* is also a form of ferric oxide. Hydrated ferric oxide, $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, together with clay and sand forms the natural earth pigment *Yellow ochre*.

Solutions of any base precipitate **ferric hydroxide**, $\text{Fe}(\text{OH})_3$, from solutions of a ferric salt:

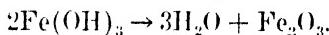


Sodium carbonate will also give this reaction:



Ferric hydroxide is the coloring principle of natural ochres.

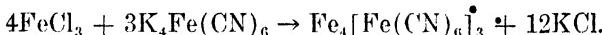
When strongly heated, ferric hydroxide loses its water of hydration, forming **ferric oxide**:



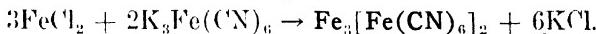
Ferrous sulphate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, known as *copperas* or *green vitriol* is used in dyeing and in making *writing ink*. *Tannic acid*, extracted from *nut-galls*, forms with ferrous sulphate a soluble almost colorless salt, *ferrous tannate*, which when exposed to air is oxidized to the ferric condition. The ferric compound is a fine black insoluble precipitate. A blue or black dye is added to give the ink temporary color.

Potassium ferrocyanide, $\text{K}_4\text{Fe}(\text{CN})_6$ called *yellow prussiate of potash* is the combination of potassium with the

complex ion $\text{Fe}(\text{CN})_6^{4-}$. Solutions of this salt do not give characteristic reactions of iron, as the iron is not present as an ion, but is part of the ion $\text{Fe}(\text{CN})_6^{4-}$ which when brought together with ferric compounds in solution, forms **ferric ferrocyanide**, $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$, known as *Prussian Blue*.



Potassium ferricyanide, $\text{K}_3\text{Fe}(\text{CN})_6$, called *red prussiate of potash* is prepared from yellow prussiate. **Turnbull's blue**, **ferrous ferricyanide**, $\text{Fe}_3[\text{Fe}(\text{CN})_6]_2$ is formed when a solution of ferrous compounds is added to a solution of potassium ferricyanide.



Blue Prints or ferrotypes receive their color from the formation of Turnbull's blue. When paper, coated with a solution of ammonium ferric citrate (called also *green scales*, which serves both as a ferric salt and as a reducing agent) and developer (potassium ferricyanide) has been exposed to light (the light effecting reduction of the ferric to ferrous compound) the color is developed and fixed in one operation by washing in water.

MANGANESE—Mn, is a steel-hard metal, chemically resembling iron. The most important compound is the dioxide, MnO_2 , which is commercially used in preparing chlorine gas:

Concentrated hydrochloric acid + manganese dioxide
→ water + manganese chloride + chlorine.

Manganese displays both metallic and non-metallic characteristics. It is found to be part of the negative bivalent ion, MnO_4^- forming manganates: potassium **manganate**, K_2MnO_4 ; and also part of the univalent ion, MnO_4^- forming permanganates: potassium **permanganate**, KMnO_4 . Potassium permanganate is of dark red color,

crystalline in form, soluble in water, yielding an intensely violet colored solution. It is a strong oxidizing agent.

Manganese borate is used in the preparation of drying oils, as is also **manganese dioxide**.

Chromium—Cr, is a blue-gray metal. Like manganese, it is added to steel to increase the hardness and tenacity, viz., *chrome steel, spiegelisen, ferro manganese*. Chromium, like iron, forms compounds rich in color, from which property it derives its name (*Chroma*, greek for color).

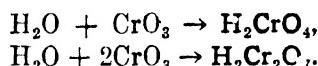
The two important oxides of chromium are **Chromic oxide**, Cr_2O_3 , of mat green color and **chromic anhydride or trioxide**, CrO_3 , soluble in water in which it yields **chromic acid**, H_2CrO_4 , of which many salts of vivid color are known.

The most important soluble salts of chromium are **potassium dichromate** and **potassium chromate**.

Potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$, is an orange-red colored crystalline salt, soluble in water.

Potassium chromate, K_2CrO_4 , is a yellow colored crystalline salt, more soluble than the dichromate.

The acid of both of these salts are formed from the anhydride, CrO_3 :



Strong acids tend to free chromic acid from either of these two salts:



Chromic acid is a very soluble substance of red color and is a powerful oxidizing agent.

Many organic substances are reduced by chromic acid. A solution of a chromate salt in sulphuric, or nitric acid (the acid in excess) will liberate chromic acid and if alcohol be added and warmed a change of color of the

solution from orange-red to green will occur. The alcohol has been oxidized to the *aldehyde*, a very volatile substance recognized by its agreeable, etherial odor. *This reaction is made use of in the detection of pigments containing the chromate radicle.*

Lead chromate, PbCrO_4 , is the most common pigment of this class, and is known as *chrome yellow*. The chromate of zinc, strontium and barium are also employed as pigments.

COBALT, Co, a hard, gray metal, very slowly acted on by acids, with exception of nitric acid in which it is readily dissolved.

Cobalt chloride, CoCl_2 , has the peculiar property of changing its color in air of varying humidity. The less hydrated condition of this salt shows blue color, the more hydrated is of red color. This property is made use of in the manufacture of inexpensive hygrometers, the change of color indicating the amount of moisture in the air.

The sulphate, CoSO_4 , nitrate, $\text{Co}(\text{NO}_3)_2$, and chloride of cobalt are soluble salts, showing the characteristic red color of solutions of cobalt salts. The pigment *Cobalt Blue* is a compound of Cobalt Oxide and Aluminum Oxide.

COPPER, Cu, is a reddish colored metal exceedingly malleable and ductile. The salts of copper are of blue or green color:

Copper sulphate, CuSO_4 . When containing water of crystallization is known as *blue vitriol*, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

Copper nitrate $\text{Cu}(\text{NO}_3)_2$.

Copper acetate, $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$ —*Verdigris*, (green) a salt of the organic acid, *acetic acid*, $\text{H}(\text{C}_2\text{H}_3\text{O}_2)$.

Ammonium hydroxide precipitates light blue *copper hydroxide*, $\text{Cu}(\text{OH})_2$, from solutions of copper salts and with the ammonium hydroxide in excess the copper hydroxide is dissolved to a deep blue solution (formation

of a soluble double salt). *This reaction is used to detect the copper ion.*

LEAD, Pb (*Plumbum*), a soft, bluish-white metal, known and used by the ancients. The most common lead ore is the sulphide, *galena*, PbS, of which large deposits are found in Missouri, Illinois and Colorado. With oxygen, lead forms several compounds:

Lead oxide, PbO, called also *massicot* when of yellow color and when solidified from the molten condition it is of reddish-yellow color and crystalline, and as such, is known as *litharge*. Pipe fitters use a cement composed of litharge and glycerine.

Red Oxide, Pb₃O₄, also, called *red lead* or *minium* is of vermillion hue and has the composition Pb₃O₄.

Lead dioxide, PbO₂, of dark brown color, also called *lead peroxide*.

Water soluble lead salts are:

Lead Nitrate, Pb(NO₃)₂.

Lead Acetate, Pb(C₂H₃O₂)₂, known commercially as *sugar of lead*. Both salts are white crystalline salts and like all compounds of lead are very poisonous.

Basic lead acetate, Pb(C₂H₃O₂)₂·OH and Pb(C₂H₃O₂)₂·2Pb(OH)₂, is formed by dissolving litharge, PbO, in a solution of lead acetate. This salt is used in preparation of basic lead carbonate Pb(OH)₂·2PbCO₃, well known as *white lead*.

Lead sulphate, PbSO₄, and **lead chloride**, PbCl₂, are practically insoluble white salts of lead.

CADMİUM, Cd, resembles the metal zinc.

Cadmium oxide, CdO, is a brown almost insoluble compound. The soluble salts of cadmium are colorless:

Cadmium sulphate, CdSO₄,

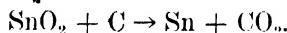
Cadmium nitrate, Cd(NO₃)₂,

Cadmium chloride, CdCl₂.

Cadmium sulphide, CdS, of bright yellow color, is the artists' pigment known as *Cadmium Yellow*.

TIN, Sn (Stannum) is a white metal, soft and malleable; and like zinc, is of crystalline structure.

Tin oxide, stannic oxide, SnO_2 a white compound, obtained from tin ores from which metallic tin is extracted by reduction:



Tin chloride, stannous chloride, SnCl_2 is the most common compound, the hydrated form of which is technically known as *tin crystals*, $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$, used extensively in mordanting and in manufacturing lake colors. It is also a powerful reducing agent.

Stannic chloride, SnCl_4 , like stannous chloride is soluble in water.

Stannic sulphide, SnS_2 , is an insoluble yellow compound, sometimes used as a pigment.

Cotton goods are made fire-proof by thoroughly impregnating them with a solution of **sodium stannate** (approximate specific gravity 1.225) the goods are then wrung out to remove excess of stannate solution, dried thoroughly and then immersed in a solution of ammonium sulphate, again squeezed and dried. After washing in clear water and drying, the fabric is rendered permanently non-flammable.

Stannic hydroxide, Sn(OH)_4 , like aluminum hydroxide has the property of forming lake colors with certain organic dyestuffs.

ANTIMONY—Sb (Stibium) a silver-white, brittle metal, with high lustre; forms two oxides:

Antimony trioxide— Sb_2O_3

Antimony pentoxide— Sb_2O_5

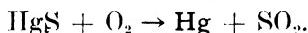
. **Lead antimoniate** is known as Naples Yellow.

The addition of antimony to certain metals forms hard alloys. *Pewter* is composed of copper, tin, lead and antimony. Antimony is also contained in *Babbitt metal*. *Type metal* is a compound of antimony, lead and tin.

BISMUTH—Bi, is more metallic than antimony, of brittle crystalline structure, heavy and of reddish color.

Bismuth alloys, having low melting points, are used in automatic sprinkler heads, as electric fuses, etc.

MERCURY, Hg (*Hydrargyrum*), at ordinary temperatures is in liquid form, of silver-white color with bright metallic lustre, frequently called *quicksilver*. The principal ore of mercury is *cinnabar* HgS, from which the metallic mercury is obtained by roasting the ore in contact with air. The sulphur is converted into gaseous sulphur dioxide and the mercury vapors are condensed and purified.



Finely divided metallic mercury and the vapor of mercury are very poisonous. Many other metals are dissolved by mercury, forming alloys, called *amalgams*. Gold dipped into mercury will become whitened by amalgamation of the mercury with the gold.

Mercurous chloride, HgCl, known as *calomel*, is a white powder, insoluble in water and used as a medicine.

Mercuric chloride, bichloride of mercury, HgCl₂ known also as *corrosive sublimate* is a white crystalline salt soluble in water (in about 14 parts). Mercuric chloride is extremely poisonous when taken internally. A dilute solution (usually 1 : 1000) is frequently used as an anti-septic in surgery.

Mercuric sulphide HgS, is known as *Vermilion*.

MAGNESIUM, Mg, is a silvery white metal of low specific gravity, readily burning in air, producing a bright light of great actinic power.

Magnesium sulphate MgSO₄.7H₂O, known as Epsom Salt soluble in water and valued medicinally for its laxative properties.

Magnesium carbonate, MgCO₃, is an insoluble, soft, very light, white powder, (*white magnesia*), sometimes

used as a base in the manufacture of lake colors. Magnesium carbonate, $MgCO_3$, found native, crystalline in structure, is called *magnesite*.

Magnesium oxide, Magnesia, MgO , is obtained by calcining magnesium carbonate. It is a fine white, voluminous, inodorous and tasteless powder, nearly insoluble in water and is sometimes used as an extender for heavy paint. It is also called *calcined magnesia*.

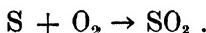
Magnesium chloride, $MgCl_2 \cdot 6H_2O$, is sometimes used in producing lake colors.

Hydrated Magnesium Silicate, $3MgO \cdot SiO_2 \cdot H_2O$, known as *Talc, Talcum, Soapstone, French Chalk and Steatite* is principally used for polishing marble, etc., and in the preparation of toilet powders, tailors' chalk, etc. *Meerschaum* is also a variety of this compound. *Asbestos* is a double silicate of magnesium and calcium.

SULPHUR—S like carbon, occurring in a number of allotropical forms, is found uncombined in nature, and also combined with many metals, forming the various metallic *sulphides* and *sulphates*.

Crude sulphur, which has been purified by heating and obtained as a fine powder, is called *flowers of sulphur*. Molten sulphur cast into molds is known as *roll sulphur*. *Orthorhombic Sulphur* is obtained as crystals, from an evaporated solution of sulphur in carbon disulphide. *Prismatic sulphur* is obtained from sulphur when cooling from a molten condition, the long, narrow, needle-like, prismatic crystals appearing on the surface. *Amorphous sulphur, plastic sulphur*, is obtained in an amorphous condition, of rubber-like consistency, when the molten sulphur is suddenly cooled. Boiling sulphur poured into cold water will cause the sulphur to assume this form, but like prismatic sulphur in a short time changes into the stable rhombic form. By dissolving sulphur in an alkali, to which hydrochloric acid is added, a finely divided precipitate is formed, which when shaken in water, forms what is known as *milk of sulphur*.

All forms of sulphur burn in presence of oxygen, forming sulphur dioxide, SO_2 :



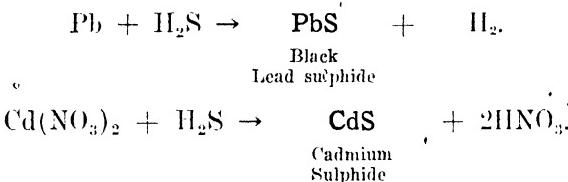
Sulphur, or some compound of sulphur is used in *vulcanizing* rubber, and also, in producing a class of dyes, *sulphur colors*.

The sulphide of many metallic elements are an important class of compounds. Cadmium sulphide and mercuric sulphide are valued as pigments. Sulphur combines with iron to form ferrous sulphide, FeS , which is mostly used in preparing hydrogen sulphide, H_2S , a colorless gas, of characteristic putrid odor.

Hydrogen sulphide is formed when organic matter, containing sulphur, decays. It is readily formed by the action of dilute hydrochloric acid on ferrous sulphide,

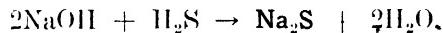


Hydrogen sulphide acts on most metals or their compounds to form the metallic sulphide:

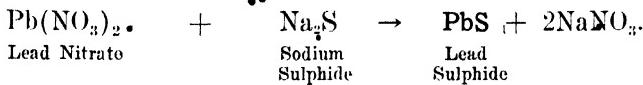


Ammonium sulphide, $(\text{NH}_4)_2\text{S}$, is obtained by treating ammonium hydroxide with hydrogen sulphide. It is a yellow colored fluid of strong disagreeable odor and reacts with metals, or their compounds, in like manner as sodium sulphide.

Sodium hydroxide with hydrogen sulphide forms **sodium sulphide**, Na_2S :



Sodium sulphide is soluble in water and reacts with metals or their compounds to form the metallic sulphide:



A solution of sodium sulphide does not have the objectionable odor, characteristic of hydrogen sulphide, and is, therefore, ordinarily used in qualitative analysis of the metals, or their compounds.

The noble metals **GOLD**, **SILVER**, and **PLATINUM** are of no importance in color chemistry.

Gold, Au, and **Platinum**, Pt, are unaffected by air or water at any temperature and by ordinary acids, but are dissolved by *aqua regia*, forming **auric chloride**, AuCl_3 and **chlorplatinic acid**, H_2PtCl_6 .

Silver, Ag, is tarnished by sulphur and acted upon by nitric and sulphuric acids. Silver is unaffected by alkalies. The coins of the United States contain 90 percent silver (900), the British coins contain 92.5 percent silver (925 fine). This latter grade of purity is called *sterling silver*.

ORGANIC CHEMISTRY

The plant and animal kingdoms are composed of organic substances, which throughout, are compounds of the element carbon. Carbon, hydrogen, oxygen, and nitrogen are the principal elements of which most organic matter is composed, sometimes sulphur and phosphorus are organic constituents. The organic compounds of the elements are very large in number and although many exist in nature, a greater number are synthetically produced.

No other element shows the tendency to combine and form such numberless and complicated compounds, as does the element carbon.

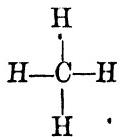
In order to more closely follow the chemical reaction of organic substances the arrangement of the atoms in a molecule are best shown by structural formulas. A *structural formula* is one, which graphically represents a molecule; thus the structural formula of carbon, the valence of which atom is four, is written



The structural formula of hydrogen, valency one, is



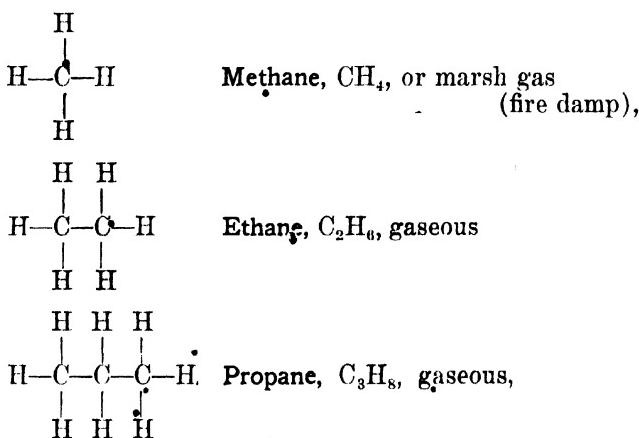
Therefore the formula of a molecule of carbon, which has united completely with hydrogen, is



This compound, CH_4 , is the beginning of a class or group of compounds, in which one or more carbon atoms are

united only with hydrogen atoms and form the group of compounds known as *hydrocarbons*.

The structural formula of these compounds the first series of which are termed the *paraffin* or *marsh gas series*, in which two adjacent carbon atoms are joined by a single bond, are:



and so on through the series:

Butane, C_4H_{10} , gaseous,
Pentane, C_5H_{12} , liquid,
Hexane, C_6H_{14} , liquid,
Heptane, C_7H_{16} , liquid,
Hexadecane, $\text{C}_{16}\text{H}_{34}$, solid,

and others. These compounds are extremely indifferent in their chemical behavior not having the properties of acids, bases, or salts.

Petroleum, in its crude state, is a complex mixture of hydrocarbons, which is partially separated by distillation into products which are still mixtures, but which, as such, are commercially used for special purposes. The components of such mixtures, as represented by petroleum,

which have the lowest boiling points, distill off first, and the condensed liquids are collected separately. This is known as *fractional distillation*. Thus petroleum is separated into the following substances:

Petroleum ether composed of pentane, hexane; with boiling point between 40°-70°,

Gasoline, (petrol) composed of hexane, heptane; with boiling point between 70°-90°,

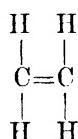
Naphtha, composed of heptane, octane; with boiling point between 80°-120°,

Benzine, composed of octane, nonane; with boiling point between 120°-150°,

Kerosene, (coal oil) composed of decane-hexadecane; with boiling point between 150°-300°.

Petrolatum (*vaseline*) and **paraffin** are further products of the fractional distillation of crude petroleum.

In the paraffin series the carbon was found to be united to the adjacent carbon atom by *one* bond. When two carbon atoms are united by a *double* bond, another series of hydrocarbons is formed, the **olefine** or **ethylene** series. The formula of this series follow the general formula C_xH_{2x} . The simplest member of this series is **olefiant gas** C_2H_4 , the graphic formula of which is:

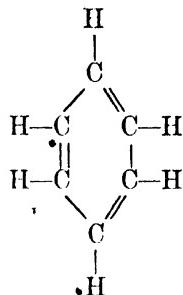


If two adjacent carbon atoms are united by a *triple* bond, they form the **acetylene** series. The general formula of this series follow the formula C_xH_{2x-2} . Thus the simplest member of this group, **acetylene**, has the formula $H-C\equiv C-H$, or C_2H_2 .

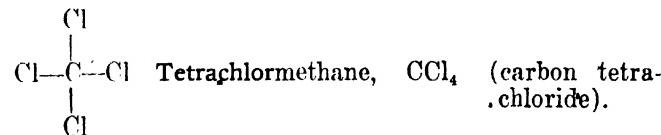
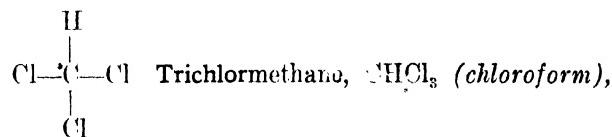
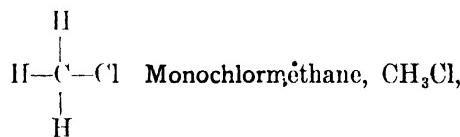
Many of the structural formulas of these compounds

show a ring formation, the substances having aromatic odors, and having been given the name **aromatic series**.

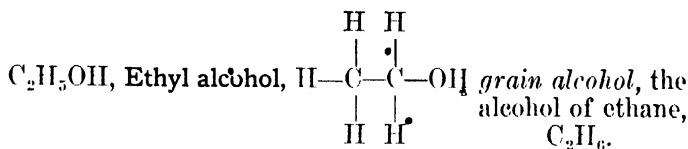
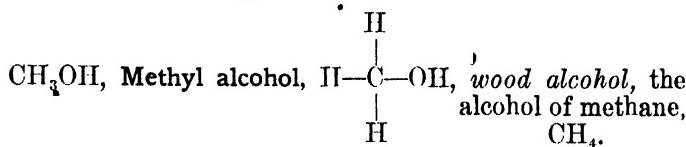
Benzene (*benzol*) C_6H_6 , derived from coal-tar, is the starting point of the aromatic series having the structural formula:



By exchanging one or more of the hydrogen atoms of the hydrocarbons, *substitution products* are obtained, thus using chlorine we obtain:



When we replace one or more of the hydrogen atoms by the corresponding number of hydroxyl groups —OH, an alcohol is formed:



and so on, by substitution, the other alcohols of this series are derived. In many alcohols the molecule has more than one —OH group. Thus *glycerine* or *glycerol*, $\text{C}_3\text{H}_5(\text{OH})_3$ is an alcohol of propane, C_3H_8 . The *sugars* are also alcohols, with several hydroxyl radicles.

Phenol or *carbolic acid*, $\text{C}_6\text{H}_5\text{OH}$, is an alcohol of benzene.

Methyl alcohol, CH_3OH (*wood alcohol*), is obtained by the destructive distillation of wood. *Gas, wood alcohol, acetone, acetic acid and charcoal*, are the most important products obtained by the destructive distillation of wood. When complex organic substances are decomposed by heat in absence of air, volatile substances and a solid residue are obtained. This process is termed, *destructive distillation*. In like manner, *illuminating gas, ammonia, tar and coke* are obtained by the destructive distillation of *soft coal*.

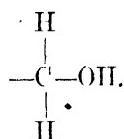
Ethyl alcohol, $\text{C}_2\text{H}_5\text{OH}$, *grain alcohol, Cologne Spirits*) is obtained by the fermentation of certain sugars by yeast; the sugars are broken up into ethyl alcohol and carbon dioxide:



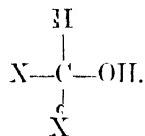
A mixture of ethyl alcohol containing about ten percent wood alcohol and about one-half percent benzene is known as *denatured alcohol*. There are several formulas for denaturing alcohol, approved by the government to meet special requirements. *Absolute alcohol* is alcohol free from water.

There are three classes of alcohols, *primary*, *secondary* and *tertiary*.

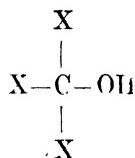
The *primary* alcohols have the $-OH$ group attached to an end carbon atom with two hydrogen atoms:



Secondary alcohols have the $-OH$ group attached to a carbon atom combined with one hydrogen atom and any other two radicles (shown as X):

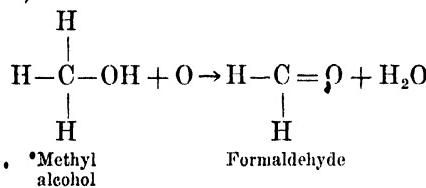


Tertiary alcohols have the $-OH$ group attached to a carbon atom, which is combined with organic radicles, but no hydrogen:



By oxidizing a primary alcohol, we obtain **aldehydes**,

thus from methyl alcohol, CH_3OH , we obtain formaldehyde H_2CH ,



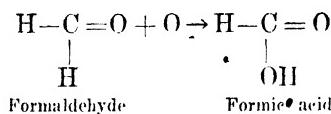
A solution containing about 40 per cent. of formaldehyde is commercially known as *formalin*.

Ketones are formed by oxidation of secondary alcohols and have the general formula,

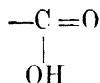


Acetone, CH_3COCH_3 is a ketone, derived from the products of the destructive distillation of wood and is principally used as a solvent for celluloid, resins, gums, acetylene gas and in the manufacture of *chloroform* and *iodoform*.

By oxidizing aldehydes, we obtain acids:



The group



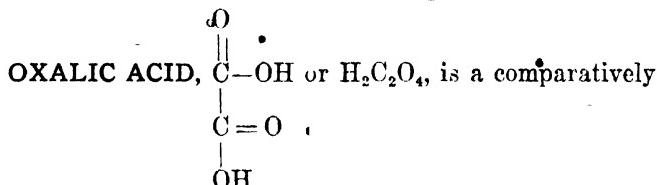
is characteristic of *organic acids* and is called the **carboxyl group**, the hydrogen of which group is replaceable by a metal. Many organic acids are of considerable commercial value.

ACETIC ACID, $\text{CH}_3-\text{C}=\text{O}$ or $\text{H}(\text{C}_2\text{H}_3\text{O}_2)$, is



the acid of vinegar, which contains about 4 percent acetic acid and is produced by the action of bacteria, *Bacterium aceticum* (*mother of vinegar*) on alcohol. Acetic acid is also formed by the destructive distillation of wood. The crude acid obtained in this manner is sometimes called **pyrolytic acid**. Acetic acid containing less than 1 percent of water is called **glacial acetic acid**.

Acetic acid is extensively used commercially, in the manufacture of white lead, coal tar colors and as a solvent for certain organic substances.



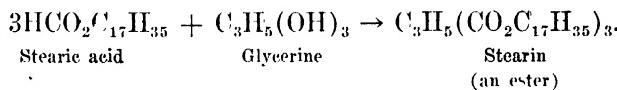
TARTARIC ACID, $\text{H}_2(\text{C}_4\text{H}_4\text{O}_6)_2$ is present in grape juice. Alcohol is formed when the sugar in the grape juice ferments, which causes the crude acid potassium salt of this acid to be deposited, as it is only slightly soluble in dilute alcohol. From this crude salt, potassium acid **tartarate** $\text{KH}(\text{C}_4\text{H}_4\text{O}_6)$, also, called *cream of tartar* and the free acid is obtained. *Cream of tartar* is a constituent of some baking powders. Potassium **antimonyl tartarate**, $\text{KSbO}(\text{C}_4\text{H}_4\text{O}_6)$ is called *tartar emetic* and is sometimes used as an emetic.

CITRIC ACID, $\text{H}_3(\text{C}_6\text{H}_5\text{O}_7)_3$, is present in the juices of lemons, oranges, limes and certain other fruits. The sharp, sour taste characteristic of the lemon is due to the presence of this acid.

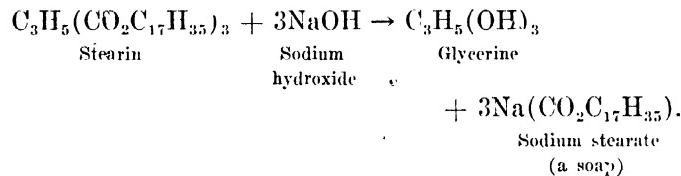
Other organic acids, less important for us, are **Benzoic Acid**, $C_6H_5CO_2H$, found in cranberries and certain other fruits. It is valued as an antiseptic.

LACTIC ACID, $HC_3H_5O_3$, is formed by the fermentation of milk sugar and is present in sour milk.

The fatty acids, the most important of which are palmitic acid, stearic acid and oleic acid are present in the various fats and oils of animal or plant origin. They are found principally combined with glycerine, (called esters); the fats or oils containing only certain proportions of the free acids.



By heating the fats or oils with alkalies, they become *saponified*, the base combining with the ester to form a *soap*, setting free the glycerine:



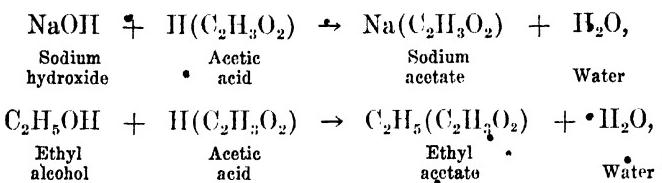
The fats and oils always contain a number of different fatty acids and their respective esters, and according to the proportion of their content, the fats or oils are fluid, semi-solid or solid.

Oleic acid and olein (the ester of oleic acid and glycerine) is fluid.

Stearic acid and palmitic acid and their esters, stearin and palmitin, are of more or less solid consistency.

When an acid and an alcohol react, an **ester** (*etheral salt*) and water are formed. This reaction is analogous to that of the formation of a salt by neutralization. In

the formation of an ester, the alcohol plays the part of a base:



The esters are widely used in making synthetic odors, perfumes and artificial fruit flavors and form a very important group of compounds.

Common ether is ethyl oxide, $(\text{C}_2\text{H}_5)_2\text{O}$, or $\text{C}_4\text{H}_{10}\text{O}$, prepared by treating alcohol with sulphuric acid.

Organic compounds in which carbon is united with hydrogen and oxygen with the latter two elements in the same proportion as in water, but not in the form of water are called carbohydrates. Common carbohydrates are the *sugars*, *starch* and *cellulose*.

The most important sugars are saccharose, glucose and fructose.

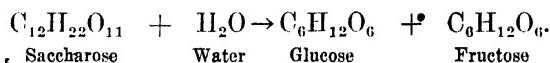
Saccharose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$, cane sugar (sucrose) and beet sugar is contained in plants such as the sugar cane and beet, which yield considerable amounts of table sugar. The sap of the sugar-maple tree also contains much of this sugar.

Molasses is the uncrystallized syrup produced in the manufacture of sugar. Molasses is sometimes misnamed treacle, which latter is a syrup obtained during the refining of sugar.

Sucrose (common sugar) crystallizes in four sided prisms (*rock candy*) melting to a colorless liquid at 160° C . and if suddenly cooled, solidifies to a transparent light yellow mass called *barley sugar*. When heated to 210° C . it partially decomposes, with loss of some water, leaving a brown mixed material, called *caramel*.

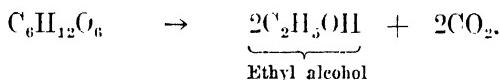
Fehling's solution is not reduced by sucrose.

By boiling saccharose with water (a trace of acid will hasten reaction) it is converted (hydrolyzed) into glucose and fructose.

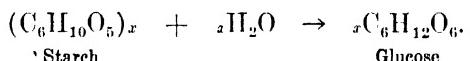


The resultant mixture of the two sugars is called invert sugar, in which each sugar interferes with the crystallization of the other, which reaction is made use of in the making of candies, which are to be pulled and icings for cakes.

The yeast plant (*yeast*) secretes two *ferments* called **zymase** and **invertase** (*sucrase*), which belong to a class of organic compounds known as **enzymes**, which are substances producing remarkable chemical changes by their mere presence. When yeast is added to a saccharose, the invertase hydrolyzes the sugar to invert sugar, which in turn is converted by zymase into alcohol and carbon dioxide:



Glucose, *dextrose* or *grape sugar*, $C_6H_{12}O_6$, is obtained from starch, by boiling with water, with addition of a dilute acid:

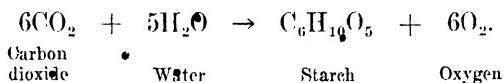


Glucose is almost colorless when pure and reduces Fehling's solution to cuprous oxide. This reaction is

* Fehling's solution is prepared by mixing equal volumes of two solutions: (1) A solution of 34.66 grams copper sulphate ($CuSO_4 \cdot 5H_2O$) in 500 cc water. (2) 173 grams *Rochelle salt*, sodium potassium tartrate, $KNaC_4H_4O_6 \cdot H_2O$, and 50 grams sodium hydroxide in 500 cc water. The two solutions should be mixed before use. When glucose in solution is added, red cuprous oxide is precipitated, when the mixture is boiled.

employed to test for glucose in the disease known as diabetes. The sugar and starch taken as food is changed to glucose and eliminated in the urine, in this disease, instead of being assimilated as they should be.

Starch, $(C_6H_{10}O_5)_n$, occurs in large quantities in wheat, oats, peas, beans, corn and in the roots, tubers (potatoes, etc.) and seeds of many plants. Starch is also present in the leaves, formed by the action of chlorophyl and sunlight on carbon dioxide and water.



Dilute solutions of iodine turn starch a deep blue color. The reaction is used to *test for either starch or iodine*.

Starch is insoluble in water but gives a transparent clear liquid when boiled with water. Many complex organic compounds, such as glues, dyes, soaps, etc. form similar clear liquids, called *colloidal suspensions*.

When dry starch is heated to about 250°C ., or if moistened and heated with dilute sulphuric acid, or nitric and hydrochloric acid for some time at about 120° it is converted into a soluble compound or mixture of compounds called **dextrine**, $(C_6H_{10}O_5)_n$, or *British gum*. It is much employed in preparing mucilage used on the backs of postage stamps and gummed labels.

CELLULOSE, $(C_6H_{10}O_5)_n$, forms the cell walls of plants. Linen and cotton are pure cellulose. Paper is made of cotton or linen rags, the cheaper kinds from wood pulp or straw. When cotton is treated with a mixture of concentrated nitric and sulphuric acids a variety of compounds, called **nitrocelluloses** are formed. *Soluble guncotton* is composed of such compounds. A solution of soluble guncotton in alcohol and ether is called *collodion*. Solutions of nitrocellulose in camphor form *celuloid*.

TABLES OF WEIGHT AND MEASUREMENT

LENGTH AND AREA

Long Measure

12 inches (in.) = 1 foot⁴ (ft.) = 30.479 centimeters
4 inches = 1 hand
3 feet = 1 yard (yd.) = 91.438 centimeters
6 feet = 1 fathom
5½ yards = 1 rod, perch or pole.
1760 yards = 1 mile (m.) = 1.6093 kilometers

Square Measure

144 sq. in. = 1 sq. ft.
9 sq. ft. = 1 sq. yd.
30¼ sq. yds. = 1 sq. rod, perch or pole
40 sq. rods. = 1 acre (43,560 sq. ft.)
640 acres = 1 sq. mile

Angular Measure

60 seconds (60") = 1 prime minute
60 minutes (60') = 1 degree (1°)
30 degrees = 1 sign (s.)
12 signs (360 degrees) = 1 great circle.

Metric System

Measures of length:

1 millimeter (mm.) = 1/1000 meter
10 millimeters = 1 centimeter (cm.) = 1/100 meter
10 centimeters = 1 decimeter (dm.) = 1/10 meter
10 decimeters = 1 meter (M.) = 39.3708 inches
10 meters = 1 decameter (Dm.) = 10 meters
10 decameters = 1 hectometer (Hm.) = 100 meters
10 hectometers = 1 kilometer (Km.) = 1000 meters = 0.6214 miles
10 kilometers = 1 myriameter (Mm.) = 10,000 meters.

Metric Square Measure

The squares of the measures of length.

WEIGHT

Avoirdupois Weight

27 $\frac{1}{4}$ grains (gr.) = 1 dram (dr.)
 16 drams = 1 ounce (oz.) 437.5 grains = 28.35 grams
 16 ounces = 1 pound (lb.) = 453.5927 grams
 14 pounds = 1 stone
 25 pounds (U. S.) = 1 quarter (Qr.)
 100 pounds (U. S.) = 1 hundred-weight (cwt.)
 20 hundred-weight = 1 ton
 2000 pounds = 1 short ton
 2240 pounds = 1 long ton

Troy Weight

Weighing of Precious Metals and Jewels

3.2 grains (gr.) = 1 carat (K) = 207.3566 milligrams
 24 grains (gr.) = 1 pennyweight (dwt.)
 20 pennyweight = 1 ounce (oz.) = 1.0971 ounces avoird. = 31.1035 grams
 12 ounces = 1 pound (lb.) = 13.1657 ounces avoird. = 373.2419 grams

Apothecaries' Weight

20 grains (gr.) = 1 scruple (s.)
 3 scruples = 1 dram (d.)
 8 drams = 1 ounce (oz.) = 1.0971 ounces avoird. = 31.1035 grams
 12 ounces = 1 pound (lb.) = 13.1657 ounces avoird. = 373.2419 grams

Metric Weight

10 milligrams (mg.) = 1 centigram (cg.)
 10 centigrams = 1 decigram (dg.)
 10 decigrams = 1 gram (g. or Gm.) 100 grams = 3.5 ounces
 10 grams = 1 decagram (Dg.)
 10 decagrams = 1 hectogram (Hg.)
 10 hectograms = 1 kilogram or kilo (Kg.) = 1000 grams = 2.2046 pounds avoird.
 10 kilograms = 1 myriagram (Mg.)
 10 myriagrams = 1 quintal
 10 quintals = 1 millier or tonneau.

VOLUME AND CAPACITY

Liquid Measure

4 gills = 1 pint (pt.) = 16 fluid ounces (fl. oz.). 1 fl. oz. = 29.57 cubic centimeter = 0.02957 liters
 2 pints = 1 quart (qt.) = 0.9105 liters
 4 quarts = 1 gallon (gal.) = 231 cubic inches U. S.
 63 gallons = 1 hogshead (hd.)
 31 $\frac{1}{2}$ gallons = 1 barrel

Apothecaries' Measure or Wine Measure

60 minimis (min.) (or drops) $\text{m} = 1$ fluid drachm or fluid dram (fl. dr.)
 or ($\frac{1}{3}$)
 8 fluid drachms $= 1$ fluid ounce (fl. oz.) or ($\frac{1}{3}$) $= 0.0296$ liters
 16 fluid ounces $= 1$ pint (octarius, Pt.) $= 0.4733$ liters
 8 pints $= 1$ gallon (congius).

Dry Measure

1 pint $= 0.5507$ liters
 2 pints $= 1$ quart (qt.) $= 1.1013$ liters
 4 quarts $= 1$ gallon (gal.)
 2 gallons $= 1$ peck (pk.)
 4 pecks $= 1$ bushel (bu.)

Cubic Measure

1728 cu. in $= 1$ cu. ft.
 27 cu. ft. $= 1$ cu. yd.
 16 cu. ft. $= 1$ cord foot
 8 cord ft. $= (128 \text{ cu ft.}) = 1$ cord

Metric Dry and Liquid Measures

Ordinary measures of volume = the cube of the measure of length.

1 milliliter (ml.) $= 1$ cubic centimeter (c. c.) $= 1/1000$ liter
 10 milliliters $= 1$ centiliter (cl.) $= 1/100$ liter
 10 centiliter $= 1$ deciliter (dl.) $= 1/10$ liter
 10 deciliter $= 1$ liter (L) $= 1000$ cubic centimeters $= 1.0567$ quarts liq.
 measure $= 61.03$ cubic inches $= 34.1$ fluid ounce U. S.
 10 liters $= 1$ decaliter (Dl.) $= 10$ liters
 10 decaliters $= 1$ hectoliter (Hl.) $= 100$ liters
 10 hectoliters $= 1$ kiloliter (Kl.) $= 1000$ liters $= 1$ cubic meter $= 61035.2$
 cubic inches $= 35.316$ cubic feet $= 1.3079$ cubic yards
 10 kiloliters $= 1$ myrialiter (Ml.) $= 10,000$ liters.

NUMBER

12 units $= 1$ dozen (doz.)
 12 dozen $= 1$ gross (gr.)
 12 gross $= 1$ great gross
 20 units $= 1$ score

PAPER

24 sheets $= 1$ quire (qr.)
 10½ quires $= 1$ token
 20 quires $= 1$ ream (rm.)
 480 sheets $= 1$ ream (U. S.)
 500 sheets $= 1$ ream (France)

TEMPERATURES

Centigrade (C°), freezing point of water = 0° C; boiling point of water = 100° C.

Fahrenheit (F°); freezing point of water = 32° F; boiling point of water = 212° F.

There are 100 degrees on the Centigrade scale between the freezing point and the boiling point of water, against 180 degrees on the Fahrenheit scale between these points, the Fahrenheit degree is therefore found to be $\frac{100}{180}$ or $\frac{5}{9}$ of 1° Centigrade. The conversion of Centigrade to Fahrenheit degrees, or vice versa, may be made by using the formulas:

$$\text{Degrees Centigrade} = \frac{5}{9} (\text{degrees Fahrenheit} - 32).$$

$$\text{Degrees Fahrenheit} = \frac{9}{5} (\text{degrees Centigrade} + 32).$$

Table of Conversion

C°	F°	C°	F°
0°	32	55	131
1	33.8	60	140
5	41	65	149
10	50	70	158
15	59	75	167
20	68	80	176
25	77	85	185
30	86	90	194
35	95	95	203
40	104	100	212
45	113		
50	122		

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